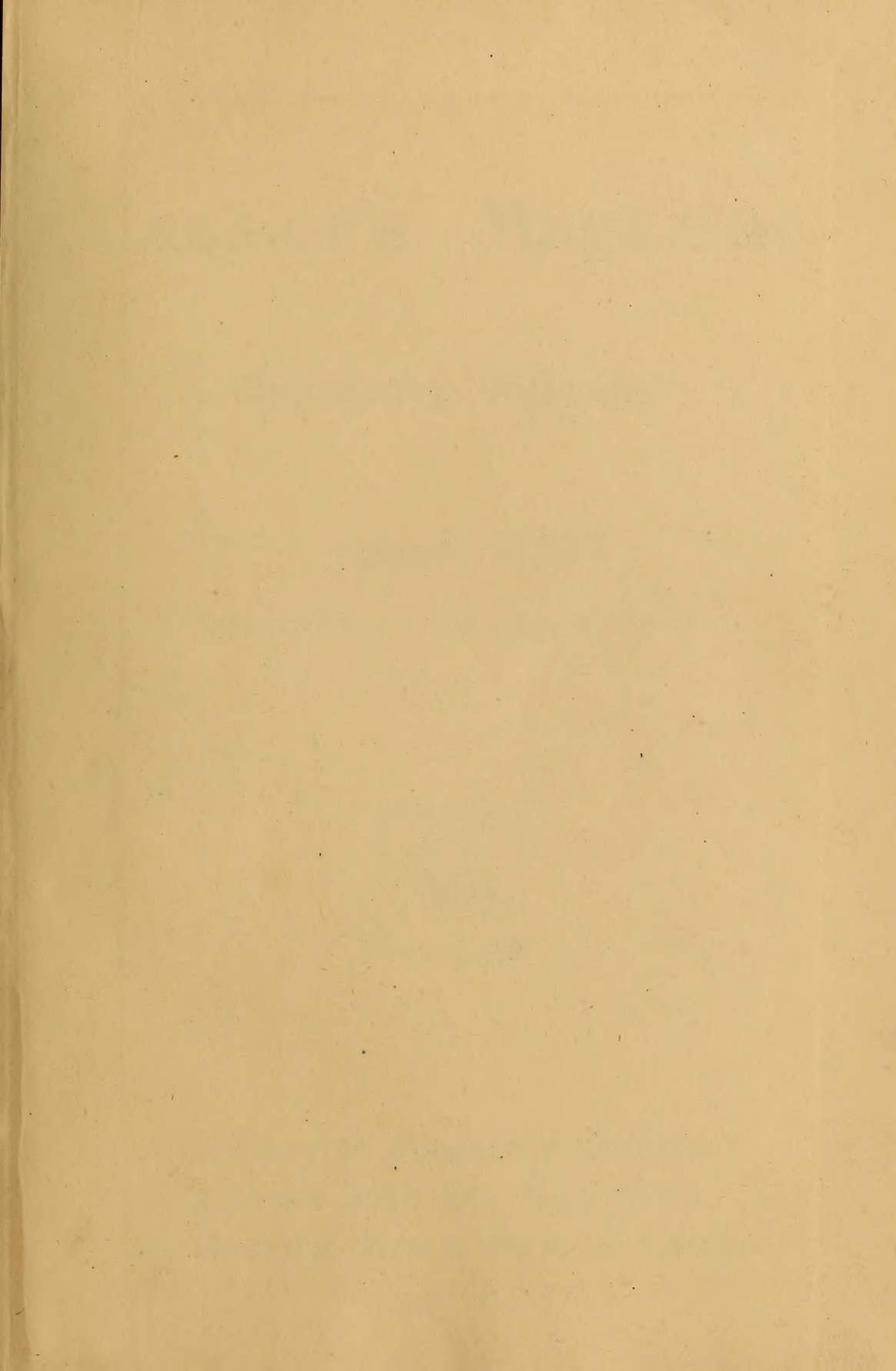


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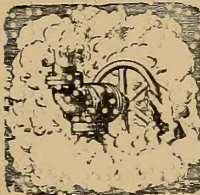
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Volume XXXI

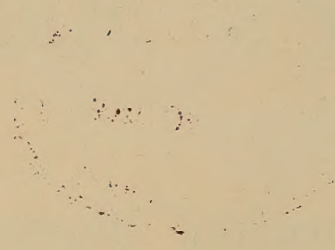
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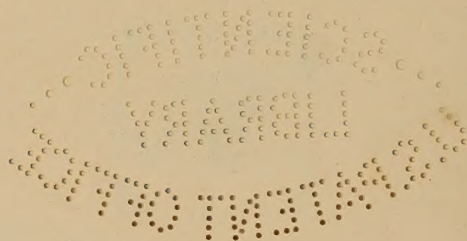
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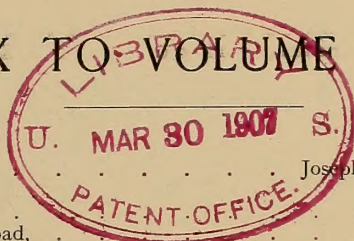
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INDEX TO VOLUME XXXI.



	PAGE
Absolute Safety at Sea, ... Joseph R. Oldham, ...	19
Illustrated.	
Abusing Valves, ...	80
Accidents in America, Railroad, ...	559
Advances in the Application of Compressed Air, Some Recent, W. L. Saunders, ...	125
Illustrated.	
Alcohol for Explosion Motors, ...	82
Alcohol, Manufacturing Costs of, ...	303
Alternating-Current Service, The Field of Electric, ... H. S. Knowlton, ...	353
American Coal Production in 1905, ...	79
America, Railroad Accidents, ...	559
America, The Apprenticeship System in, ... Luther D. Burlingame	72
America, Transportation Problems in, ...	559
Applications of the Telephone, Widening, ... William Maver, Jr., ...	275
Illustrated.	
Apprenticeship and Technical Training, ...	357
Apprenticeship System in America, The, ... Luther D. Burlingame, ...	72
Architect and the Central Station, The, ... S. Morgan Bushnell, ...	261
Architecture, Naval, ...	268
Arc Lamp, The Magnetite, ... J. L. R. Hyden, ...	304
Illustrated.	
Armengaud, René, The Gas Turbine, ...	187
Illustrated.	
Art of Water Softening, The Present Status of the, ... George C. Whipple, ...	416
Illustrated.	
Automobile Propulsion, The Gas Turbine for, ... W. H. Stuart-Garnett, ...	410
Benjamin, C. H.: Smoke Prevention in the Power House, ...	339
Illustrated.	
Bignami, Enrico: Recent Hydraulic Power Developments in Switzerland	309
Illustrated.	
BIOGRAPHICAL SKETCHES:	
Diesel, Rudolph, ... E. D. Meier, ...	560
Dunn, Gano S., ... Rodman Gilder, ...	367
Green, Sir Edward, Bart, ...	88
Rice, Calvin Winsor, ... John W. Lieb, Jr., ...	173
Sergeant, Henry C., ...	463
Taylor, Frank H., ...	272
Blower, The Realm of the Fan, ... Walter B. Snow, ...	63
Illustrated.	
Boilers and Engines, Construction, Inspection of, ... J. R. Thompson, ...	321, 442, 539
Illustrated.	
Booth, W. H.: Small British Steam Engines, ...	113
Illustrated.	
Breakages of Rails, ...	559
Brooking, J. H. C.: Electric Cable Troubles, ...	131
Brown, C. S. Vesey: The Electrical Power Supply of London, ...	507
Illustrated.	
Burlingame, Luther D.: The Apprenticeship System in America.	72
Bushnell, S. Morgan, The Architect and the Central Station, ...	261
Business, Getting New and Holding the Old, ... R. L. Goodale, ...	58
Cable Troubles, Electric, ... J. H. C. Brooking, ...	131
Canada, Niagara Hydraulic Power, In, ...	358
Canal, Progress on the Panama, ... Fullerton L. Waldo, ...	283
Illustrated.	
Capability, Warship Building, ...	271
Castings and Their Application, In Machine Construction, ...	
The Production of Malleable, ... Dr. Richard Moldenke, ...	211

	PAGE
Cataract of Iguazu, The, ...	Henry Harley, ... 467
Illustrated.	
Causes and Preventions of Disasters in Mines, ...	G. Farmer, ... 296
Central Station, The Architect and the, ...	S. Morgan Bushnell, ... 261
Channel Tunnel, The, ...	 457
Coal Production in 1905, American, ...	 79
Combustion, A Peculiar Case of Spontaneous, ...	S. E. Worrell, ... 77
Concrete in Power Station Construction, Reinforced, ...	H. L. Knowlton, ... 486
Illustrated.	
Concrete Without Water, ...	 79
Construction Inspection of Boilers and Engines, ...	J. R. Thompson, ... 321, 442, 539
Illustrated.	
Construction, Materials of, ...	 458
Construction, Reinforced Concrete in Power Station, ...	H. L. Knowlton, ... 486
Illustrated.	
Cranes, Foundry, ...	 458
Cutting of Metals, The, ...	 267
Design, Motor Car, ...	 462
Disasters in Mines, Causes and Preventions of, ...	G. Farmer, ... 296
Distribution of Power from Furnace Gases, ...	 365
Eastwood, Arthur C.: Lifting Magnets, ...	 91
Illustrated.	
Electrical Power Supply of London, The, ...	C. S. Vesey Brown, ... 507
Illustrated.	
Electric Alternating-Current Service, The Field of, ...	H. S. Knowlton, ... 353
Electric Cable Troubles, ...	J. H. C. Brooking, ... 131
Electric Hoists in Building Construction, ...	 87
Electricity, Gas vs., ...	Geoffrey M. Gill, ... 56
Electricity in the Home, ...	H. W. Hillman, ... 25
Illustrated.	
Electric Power on the Rand, ...	 360
Electric Railways, Gases as a Source of Power for the Opera- tion of, ...	F. E. Junge, ... 479
Electric Water Heating, ...	 78
Engineering Evolution, ...	 270
Engineering Meetings, ...	 267
Engineering, Theory and Practice in, ...	 460
Engineering, Wire Rope Tramway, ...	S. S. Webber, ... 142
Illustrated.	
Engineer, The Work of the, ...	 266
Engines, Foundations for Pumping, ...	Charles A. Hague, ... 42
Engines, Small British Steam, ...	W. H. Booth, ... 113
Illustrated.	
Evolution, Engineering, ...	 270
Export, The Packing of Machinery for, ...	W. E. Partridge, ... 551
Illustrated.	
Exposition of Safety Devices, ...	 171
Factories, Modern, ...	 459
Facts About the German Navy, The Real, ...	Archibald S. Hurd, ... 371
Illustrated.	
Fan Blower, The Realm of the, ...	Walter B. Snow, ... 63
Illustrated.	
Farmer, G.: Causes and Preventions of Disasters in Mines, ...	 296
Faults in Machine Design, Minor, ...	 364
Field of Electric Alternating-Current Service, The, ...	H. S. Knowlton, ... 353
Foundations for Pumping Engines, ...	Charles A. Hague, ... 42
Foundry Cranes, ...	 458
Fry, Lawford H.: The Steam Locomotive of the Future, ...	 216
Illustrated.	
Furnace Gases, Distribution of Power, ...	 365
Garnett, W. H. Stuart: The Stability of Submarines, ...	 235
Illustrated.	
Gases as a Source of Power for the Operation of Electric Railways, ...	F. E. Junge, ... 479
Gas Heating Stove, A Novel Form of, ...	William Paul Gerhard, ... 52
Illustrated.	
Gas Turbine for Automobile Propulsion, The, ...	W. H. Stuart-Garnett, ... 410
Gas Turbine, The, ...	René Armengaud, ... 187
Illustrated.	

INDEX

V

	PAGE
Gas vs. Electricity, ...	Geoffrey M. Gill, ... 56
Gear Cutting Machinery, Modern, ...	Joseph Horner, ... 520
Illustrated.	
Gerhard, William Paul: A Novel Form of Gas Heating Stove, ...	52
Illustrated.	
German Naval Developments, ...	455
German Navy, The Real Facts About the, ...	Archibald S. Hurd, ... 371
Illustrated.	
Getting New Business and Holding the Old, ...	R. L. Goodale, ... 58
Gibson, A. H.: The Steam Turbine, ...	36
Gill, Geoffrey M.: Gas vs. Electricity, ...	56
Gold, The Increased Production of, and Its Relation to the	
Standard of Value, ...	Alexander E. Outerbridge, Jr. 388
Goodale, R. L.: Getting New Business and Holding the Old, ...	58
Gross, Robert J.: The Industrial and Commercial Possibilities of Russia, ...	138
Hague, Charles A.: Foundations for Pumping Engines, ...	42
Harley, Henry: The Cataract of Iguazu, ...	467
Illustrated.	
Hart, Joseph H.: Refrigeration on Shipboard, ...	437
Hillman, H. W.: Electricity in the Home, ...	25
Illustrated.	
Home, Electricity in the, ...	H. W. Hillman, ... 25
Illustrated.	
Horner, Joseph: Modern Machine Shop Requirements, ...	156
Illustrated.	
Modern Machine Shop Requirements, ...	242
Illustrated.	
Modern Gear Cutting Machinery, ...	520
Illustrated.	
Hurd, Archibald S.: The Real Facts About the German Navy, ...	371
Illustrated.	
Hyden, J. L. R.: The Magnetite Arc Lamp, ...	304
Illustrated.	
Hydraulic Power Developments in Switzerland, Recent, ...	Enrico Bignami, ... 309
Illustrated.	
Hydro-Electric Power Plant, The Shawinigan, ...	Wallace C. Johnson, ... 394
Illustrated.	
Iguazu, The Cataract of, ...	Henry Harley, ... 467
Illustrated.	
Illumination, Machine Shop, ...	461
Increased Production of Gold and Its Relation to the Stand-	
ard of Value, The, ...	Alexander E. Outerbridge, Jr. 388
Induction Motors vs. Direct-Current Motors for Factory Use, ...	172
Industrial and Commercial Possibilities of Russia, The, ...	Robert J. Gross, ... 138
Ineffectiveness of Night Work, ...	177
Influence of the Engineer, ...	88
Inspection of Boilers and Engines, Construction, ...	J. R. Thompson, ... 321, 442, 539
Illustrated.	
Insulation of Insulators, The, ...	84
Johnson, Wallace C.: The Shawinigan Hydro-Electric Power Plant, ...	394
Illustrated.	
Junge, F. E.: Gases as a Source of Power for the Operation of Electric Railways, ...	479
Knowlton, H. L.: Reinforced Concrete in Power Station Construction, ...	486
Knowlton, H. S.: The Field of Electric Alternating-Current Service, ...	353
Lamp, The Magnetite Arc, ...	J. L. R. Hyden, ... 304
Illustrated.	
Lifting Magnets, ...	Arthur C. Eastwood, ... 91
Illustrated.	
Locomotive of the Future, The Steam, ...	Lawford H. Fry, ... 216
Illustrated.	
Locomotive Problems, ...	179
London, The Electrical Power Supply of, ...	C. S. Vesey Brown, ... 507
Illustrated.	
Long Distance Power Transmission with Direct Currents, ...	C. T. Wilkinson, ... 199
Illustrated.	
Machine Design, Minor Faults in, ...	364
Machinery for Export, The Packing of, ...	W. E. Partridge, ... 551
Illustrated.	

	PAGE
Machinery, Modern Gear Cutting, ...	Joseph Horner, ... 520
Illustrated.	
Machine Shop Illumination, ...	461
Machine Shop Requirements, Modern, ...	Joseph Horner, ... 156, 242
Illustrated.	
Magnetite Arc Lamp, The, ...	J. L. R. Hyden, ... 304
Illustrated.	
Magnets, Lifting, ...	Arthur C. Eastwood, ... 91
Illustrated.	
Malleable Castings and Their Application in Machine Construction, The Production of, ...	Dr. Richard Moldenke, ... 211
Management, Modern Factory, ...	Egbert P. Watson, ... 106
Manufacturing Costs of Alcohol, ...	363
Marine Boilers, Water-Tube, ...	83
Materials of Construction, ...	458
Maver, William: Multiplex Telegraphy, ...	167
Illustrated.	
Widening Applications of the Telephone, ...	275
Meetings, Engineering, ...	267
Metals, The Cutting of, ...	267
Metric System in France, The, ...	359
Mexico and Her Opportunities, ...	Winthrop Scarritt, ... 3
Illustrated.	
Mines, Causes and Preventions of Disasters in, ...	296
Minor Faults in Machine Design, ...	364
Model Testing Tanks, ...	268
Modern Factories, ...	459
Modern Factory Management, ...	Egbert P. Watson, ... 106
Modern Gear Cutting Machinery, ...	Joseph Horner, ... 520
Illustrated.	
Modern Machine Shop Requirements, ...	Joseph Horner, ... 156, 242
Illustrated.	
Moldenke, Dr. Richard: The Production of Malleable Castings and their Application in Machine Construction, ...	211
Motors, Alcohol for Explosion, ...	82
Motor Car Designing, ...	462
Multiplex Telegraphy, ...	William Maver, ... 167
Illustrated.	
Municipal Transport Problems, ...	456
Naval Architecture, ...	268
Naval Developments, German, ...	455
Navy, The Real Facts About the German, ...	Archibald S. Hurd, ... 371
Illustrated.	
Niagara Hydraulic Power in Canada, ...	358
Night Work, Ineffectiveness of, ...	177
Novel Form of Gas Heating Stove, A, ...	William Paul Gerhard, ... 52
Illustrated.	
Oldham, Joseph R.: Absolute Safety at Sea, ...	19
Illustrated.	
Operation of Electric Railways, Gases as a Source of Power F. E. Junge, ...	479
Outerbridge, Alexander E., Jr.: The Increased Production of Gold and Its Relation to the Standard of Value, ...	388
Packing of Machinery for Export, The, ...	W. E. Partridge, ... 551
Illustrated.	
Panama Canal, Progress on the, ...	Fullerton L. Waldo, ... 283
Illustrated.	
Panama Canal, Work on the, ...	269
Panama, The President at, ...	265
Partridge, W. E.: The Packing of Machinery for Export, ...	551
Illustrated.	
Peculiar Case of Spontaneous Combustion, A, ...	S. E. Worrell, ... 77
Possibilities of Russia, The Industrial and Commercial, ...	Robert J. Gross, ... 138
PORTRAITS:	
Diesel, Rudolph, ...	466
Dunn, Gano S., ...	274
Green, Sir Edward, Bart, ...	2
Rice, Calvin Winsor, ...	90
Sergeant, Henry C., ...	370
Taylor, Frank H., ...	186

	PAGE
Power House, Smoke Prevention in the, ... C. H. Benjamin, ...	339
Illustrated.	
Power on the Rand, Electric, ...	360
Power Plant Economies, ...	85
Power Plant, The Shawinigan Hydro-Electric, ... Wallace C. Johnson, ...	394
Illustrated.	
Power Production, Refrigeration and, ...	366
Power Scheme, The Victoria Falls, ...	361
Power Station Construction, Reinforced Concrete in, ... H. L. Knowlton, ...	486
Illustrated.	
Power Transmission with Direct Currents, Long Distance, C. T. Wilkinson, ...	109
Illustrated.	
Present Status of the Art of Water Softening, ... George C. Whipple, ...	416
Illustrated.	
President at Panama, The, ...	265
Problems, Municipal Transport, ...	456
Production of Gold and Its Relation to the Standard of Value, The Increased, ... Alexander E. Outerbridge, Jr.	388
Production of Malleable Castings and Their Application in Machine Construction, The, ... Dr. Richard Moldenke, ...	211
Progress on the Panama Canal, ... Fullerton L. Waldo, ...	283
Illustrated.	
Propulsion, The Gas Turbine for Automobile, ... W. H. Stuart-Garnett, ...	410
Pumping Engines, Foundations for, ... Charles A. Hague, ...	42
Rail Breakages, ...	559
Railroad Accidents in America, ...	559
Real Facts About the German Navy, The, ... Archibald S. Hurd, ...	371
Illustrated.	
Realm of the Fan Blower, The, ... Walter B. Snow, ...	63
Illustrated.	
Recent Advances in the Application of Compressed Air, W. L. Saunders, ...	125
Illustrated.	
Recent Hydraulic Power Developments in Switzerland, ... Enrico Bignami, ...	309
Illustrated.	
Refrigeration and Power Production, ...	366
Refrigeration on Shipboard, ... Joseph H. Hart, ...	437
Reinforced Concrete in Power Station Construction, ... H. L. Knowlton, ...	486
Illustrated.	
Removing Blast-Furnace Obstructions, Use of Oxygen in, ...	181
Rope Tramway Engineering, Wire, ... S. S. Webber, ...	142
Illustrated.	
Safety at Sea, Absolute, ... Joseph R. Oldham, ...	19
Illustrated.	
Saunders, W. L.: Some Recent Advances in the Application of Compressed Air, ...	125
Illustrated.	
Scarritt, Winthrop, Mexico and Her Opportunities, ...	3
Illustrated.	
Sea, Absolute Safety at, ... Joseph R. Oldham, ...	19
Illustrated.	
Shawinigan Hydro-Electric Power Plant, The, ... Wallace C. Johnson, ...	394
Illustrated.	
Shipboard, Refrigeration on, ... Joseph H. Hart, ...	437
Sir Edward Green and the Fuel Economizer, ...	88
Small British Steam Engines, ... W. H. Booth, ...	113
Illustrated.	
Smoke Prevention in the Power House, ... C. H. Benjamin, ...	339
Illustrated.	
Snow, Walter B.: The Realm of the Fan Blower, ...	63
Illustrated.	
Some Recent Advances in the Application of Compressed Air W. L. Saunders, ...	125
Illustrated.	
Spontaneous Combustion, A Peculiar Case of, ... S. E. Worrell, ...	77
Stability of Submarines, The, ... W. H. Stuart-Garnett, ...	235
Illustrated.	
Station, The Architect and the Central, ... S. Morgan Bushnell, ...	261
Steam Engines, Small British, ... W. H. Booth, ...	113
Illustrated.	

	PAGE
Steam Locomotive of the Future, The, ... Lawford H. Fry, ...	216
Illustrated.	
Steam Navigation and Sea Power, ...	455
Steam Turbine Ships, ...	84
Steam Turbine, The, ... A. H. Gibson, ...	36
Stove, A Novel Form of Gas Heating, ... William Paul Gerhard, ...	52
Illustrated.	
Stuart-Garnett, W. H.: The Gas Turbine for Automobile Propulsion, ...	410
Submarines, The Stability of, ... W. H. Stuart-Garnett, ...	235
Illustrated.	
Tanks, Model Testing, ...	268
Technical Training, Apprenticeship and, ...	357
Telegraphy, Multiplex, ... William Maver, ...	167
Illustrated.	
Telephone, Widening Applications of the, ... William Maver, Jr., ...	275
Illustrated.	
Testing Tanks, Model, ...	268
Theory and Practice in Engineering, ...	459
Thompson, J. R.: Construction Inspection of Boilers and Engines, ... 321, 442, 539	
Illustrated.	
Tramway Engineering, Wire Rope, ... S. S. Webber, ...	142
Illustrated.	
Transmission with Direct Currents, Long Distance Power, C. T. Wilkinson, ...	199
Illustrated.	
Transport Problems, Municipal, ...	456
Transportation Problems in America, ...	559
Troubles, Electric Cable, ... J. H. C. Brooking, ...	131
Tunnels, Great, ...	175
Tunnel, The Channel, ...	457
Turbine for Automobile Propulsion, The Gas, ... H. W. Stuart-Garnett, ...	410
Turbine Ships, Steam, ...	84
Turbine, The Gas, ... René Armengaud, ...	187
Illustrated.	
Turbine, The Steam, ... A. H. Gibson, ...	36
Use of Oxygen in Removing Blast-Furnace Obstructions, ...	181
Utilization of Natural Waterfalls, ...	558
Valves, Abusing, ...	80
Vesey-Brown, C. S.: Electric Power Supply of London, ...	507
Victoria Falls Power Scheme, The, ...	361
Voltages in Electric Isolated Plants, ...	171
Waldo, Fullerton L.: Progress on the Panama Canal, ...	283
Illustrated.	
Warship Building Capability, ...	271
Waterfalls, Utilization of Natural, ...	558
Water Heating, Electric, ...	78
Water Softening, The Present Status of the Art of, ... George C. Whipple, ...	416
Illustrated.	
Water-Tube Marine Boilers, ...	83
Watson, Egbert P.: Modern Factory Management, ...	106
Whipple, George C.: The Present Status of the Art of Water Softening, ...	416
Illustrated.	
Widening Applications of the Telephone, ... William Maver, Jr., ...	275
Illustrated.	
Wilkinson, C. T.: Long-Distance Power Transmission with Direct Currents, ...	199
Wireless Telegraphy Developments, ...	172
Wire Rope Tramway Engineering, ... S. S. Webber, ...	142
Illustrated.	
Work of the Engineer, The, ...	266
Work on the Panama Canal, ...	260
Worrell, S. E.: A Peculiar Case of Spontaneous Combustion, ...	77

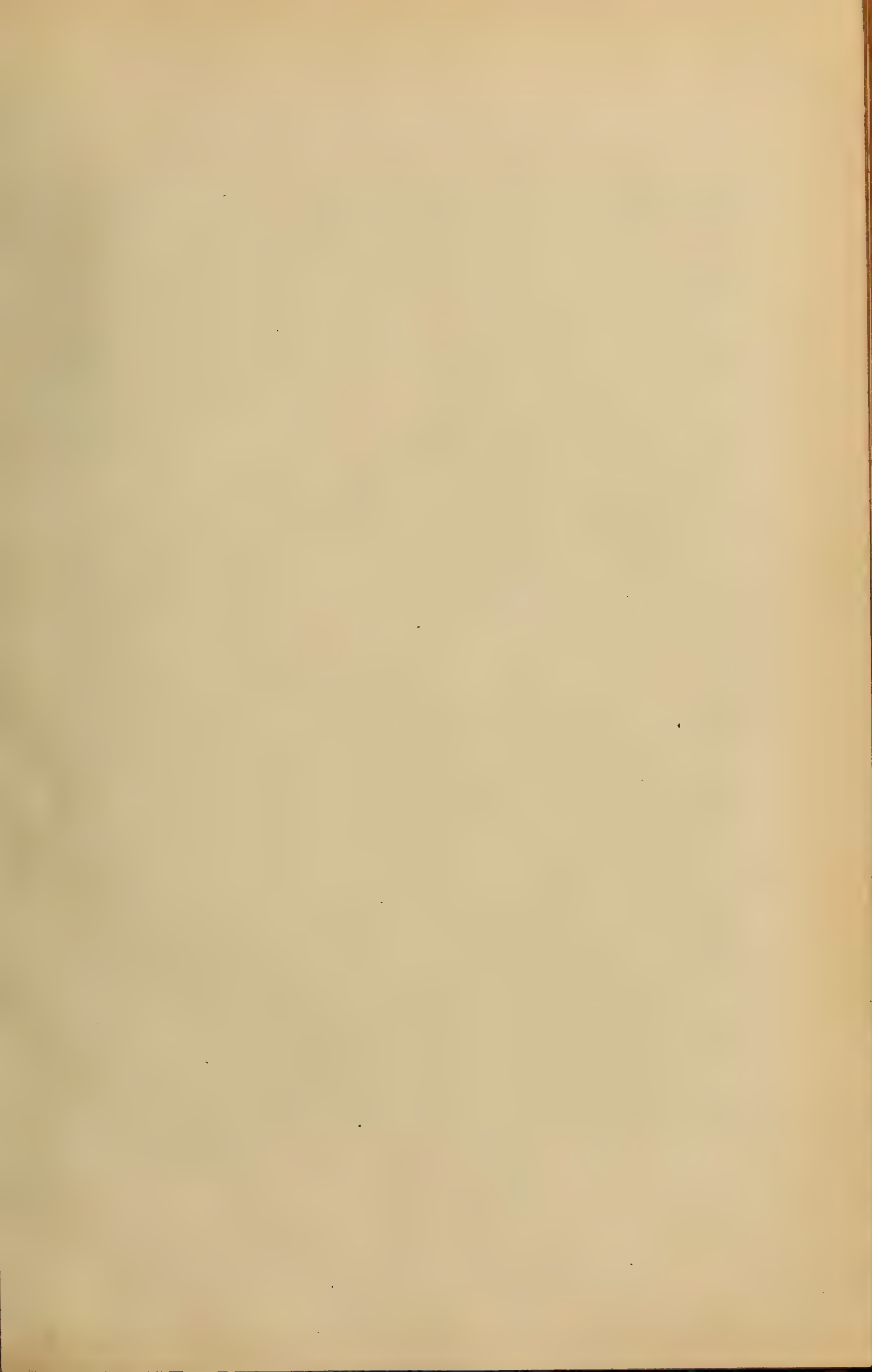




PHOTO BY C. & J. HALL, WAKEFIELD, ENGLAND

SIR EDWARD GREEN, BART

THE ORIGINAL MAKER OF THE GREEN FUEL ECONOMIZER

SEE PAGE 88

INDEXED

CASSIER'S MAGAZINE

Vol. XXXI

NOVEMBER, 1906

No. 1

MEXICO AND HER OPPORTUNITIES

By Winthrop Scarritt

"Westward the course of empire takes its way;
The four first acts already past,
A fifth shall close the drama with the day;
Time's noblest offspring is the last."

THUS sang far-seeing Bishop Berkeley. Since the dawn of history man has been migrating across parallels of longitude westward. From his cradle on the banks of the Euphrates the race instinct has impelled him to travel always towards the west. First over Asia, thence across Europe until finally Columbus turned the prow of his little craft towards the unknown world of the West. In all the annals of human history there is no record of grander daring or sublimer faith than this act of the sailor of Genoa. Some one has well said that to reward a faith like that of Columbus the almighty would have raised a continent out of the sea.

Turning to another page of history we see the Pilgrim Fathers landing on "a stern and rock-bound coast." It is well they landed at Plymouth Rock and fought out there under hard conditions the battle for existence, for we are told that had the first settlers entered America through the Golden Gate, and settled along the fertile shores of the Pacific slope, New England would still be a deso-

late waste. But westward, still westward, the migratory instinct drove our fathers. First the Middle West; then came, within the easy memory of the present generation, the winning of the Far West until the Pacific slope by the steel bands of commerce was bound to the East.

But not yet was the restless spirit of Anglo-Saxon civilization satisfied. It leaped the Pacific, and, resting for a breath on the island of Hawaii, sailed with Dewey on that ever me-



SLIDING DOWN MT. POPOCATAPETL



A BIT OF RAILWAY CONSTRUCTION IN THE TEMASOPA CANON

morable morning in May into the harbour of Manila, and the Philippine Islands, like ripe fruit, fell into the lap of Uncle Sam.

Alexander, still in his youth, wept when there were no more worlds to conquer. Now that the earth has been encircled and there are no more degrees of longitude to be captured, what is the nervous, impetuous Anglo-Saxon spirit to do next?

Too often, alas, in human history has this spirit manifested itself in war. Today, however, it finds full

field for its activities in the peaceful pursuits of business and commerce, so that, parallels of longitude having been exhausted, capital and enterprise have turned towards parallels of latitude. In their shining pathway lies the illimitable untold wealth of America's nearest latitudinal neighbour, Mexico. If to-day Berkeley were writing, he would say, "Southward the star of progress takes its way."

The writer's opportunity to visit the land of the Aztecs came about

unexpectedly thus:—He is known as an enthusiastic automobilist and one day was thus greeted by a friend:—"Come with me to Mexico and I will give you some rough riding in an automobile into the heart of the Sierra Madre mountains where the neigh of the horseless steed has never been heard."

Here was offered an opportunity to penetrate the mountains of Mexico and I could not resist the temptation. Forty-eight hours later I found myself on board a private car with a congenial company, and our long journey was begun. Without incident we continued our Westward way, from New York, via Chicago, Kansas City and Albuquerque, to El Paso. There we crossed the Rio

knows about Mexico. The result was, I must confess, a bit surprising and humiliating. I began to "pump" my traveling companions, and, alas, found them as deficient in knowledge of the country as myself. I take it therefore that the average reader would welcome a bit of accurate historical and other information.

To begin with, Mexico is, roughly speaking, a big country nineteen hundred and fifty miles long and seven hundred and fifty miles wide at the widest point. This is an area equal to that of Great Britain, Ireland, France, Germany and Austria-Hungary. Washed by the peaceful waters of the Pacific on the west and by those of the salubrious Gulf on the east, there is no more per-



A RAILWAY BRIDGE NEAR ENCARNACION

Grande and at Juarez found ourselves under the flag of the Republic of the Southwest.

Standing for the first time on Mexican soil, one naturally begins to take a mental inventory of what he

fect climate on the globe than that of Mexico. Throughout the winter the sun shines from the deep blue of cloudless skies; in summer there are frequent cooling showers, and the climate, except perhaps along the



THE FALLS OF JUANACATLAN, ONE OF MANY PROMISING WATER POWERS

low lands of the coast, is delightful. The city of Mexico is regarded as a veritable sanitarium.

Along the east coast the ground is low. Then come the terraces or table lands, and still further westward the mountainous regions and high elevations. On the table lands of the interior, for countless miles, are desolate stretches of bare, sun-scorched plains. The traveler gazes from the car window for hours at sand and cactus and an occasional jack rabbit scurrying off across the plain, and wonders whether the soil will ever be productive. Suddenly he comes to a little stream from which an irrigating ditch leads to a nearby field. Behold the magic transformation. Here is an emerald isle of growing grain, a very oasis in the desert and you hold it in your eye as long as vision lets you and then in pleasant memory for many a happy day thereafter.

The history of Mexico is as fascinating as a rare novel. Merging out the shadowy realm of tradition, we know that the Toltecs appeared in 648 A. D. and the Aztecs in 1196. The Empire of the Montezumas was set up about 1460 and survived until the arrival of Cortez and his Spanish soldiers in 1519. Without serious opposition, Cortez captured the ancient capital now known as the city of Mexico. Later he was driven out, but, reinforcements arriving from Cuba, he again successfully attacked the city. Powder for his nine small cannon and fire-arms was made from the sulphur taken from the volcanic crater, Popocatepetl.

In 1627 there was an uprising of the Opatá Indians in northern Mexico, and all the Spaniards were massacred. The historian Prescott relates that the city of Mexico was originally built by the Aztecs on an island in Lake Mexico, and at the time of the Spanish Conquest was like Venice in that it had canals instead of streets. In 1629 the city was so suddenly inundated that thirty thousand people lost their lives.

For three-hundred years Mexico was under Spanish rule. Following Spanish history everywhere, oppression and tyranny were the hard lot of the Mexicans. Revolutions were fomented. In 1810 a patriot and priest, Hidalgo, organized a revolution. His plans were discovered and he was compelled to assume hostilities before he was prepared. After some victories and more reverses, the heroic band of patriots was betrayed to the Spaniards. On July 31, 1811, Hidalgo was shot at Chihuahua. Standing on the spot where he was executed, a splendid monument bears enduring testimony to his valour and to his abiding place in the hearts of his countrymen. Finally Yturbide's army, known as the "Army of the Three Guarantees," achieved the independence of Mexico. At that time Mexico included Guatemala, all of the present republic, and that part of the United States from the Arkansas and Red Rivers to the Pacific Ocean, extending far northward to the British possessions, and was one of the greatest empires on earth.

On May 19, 1822, Yturbide was elected by Congress as emperor, bearing the title of Augustin I. But the empire soon fell and a republic was proclaimed by General Santa Anna. The first real Congress of the Republic, made up at the present time of twenty-eight states, having an aggregate population of about 14,000,000 people, assembled in the capital on November 7, 1823, and adopted a constitution very like that of the United States. In 1835 Texas seceded from Mexico and set up a republican form of government. Texas continued as an independent republic until 1844 and as such was recognized by foreign powers. On April 12, 1844, a treaty was made with Texas by which she was admitted into the union of the United States of America. This angered Mexico and she went to war. This was ended by the treaty of Guadalupe-Hildago on February 2, 1848,



MEXICAN WATER CARRIERS

by which, on the payment of \$15,000,000, Mexico ceded to the United States all the territory north and east of the Rio Grande. The total area ceded exceeded 930,000 square miles.

The aborigines of Mexico must have reached a high degree of civilization. A distinguished writer says:—"The skill shown in their architecture and sculpture, as evidenced in the vast ruins of their cities, the astronomic and mathematical knowledge recorded in the Aztec calendar stone, the highly developed systems of writing of the Aztecs and Mayas, their military and civil organization, were no doubt the patrimony of a comparatively small class segregated from the bulk of the population by long selection; but this is true of all civilizations and the very fact that the development of such a class was possible proves that its elements pre-existed in the race at large."

Spanish is the official language of the country, but there are more than

2,000,000 people whose native tongue is some Indian language. The Statesman's Year Book states that whites form 19 per cent. of the population; the mixed race forms 43 and the Indians form 38 per cent. These figures can be only approximately correct. The population is estimated at 16.4 inhabitants per square mile. The Spanish characteristics are those of great endurance, courtesy, and a chivalrous love of adventure. One thing that surprised the early Spanish invaders is the natural ability of the natives as runners. Montezuma often dined on fish caught 24 hours before from the Gulf of Mexico 250 miles away and brought to his capital by fleet-footed runners.

In 1803 that great scholar and scientist, Von Humboldt, whose visit has been termed as "the second conquest of Mexico," was astonished at the facilities for higher education in the city of Mexico. He wrote, "No city in the New World, not except-

ing those of the United States, has scientific establishments as grand and solid as those of the Mexican capital."

Cortez captured the ancient city of Mexico on August 23, 1521, and in the following year it had school houses accommodating a thousand pupils. Eight years later the college of San Juan de Letras was established. In 1553 the University of Mexico was established.

public schools, in her colleges and museums and art galleries, the city of Mexico will compare well, yea, surpass, most American cities, so that not infrequently the captious traveller who goes to carp and criticise remains to appreciate and rapturously admire.

In the art gallery are to be seen the handiwork of such masters as Aguirre, Velasquez, Murillo, Rubens, and Van Dyke. The commerce be-



A VIEW IN GUANAJUATO

It is ludicrous to observe the patronizing air with which some Americans have visited the city of Mexico, until they have grasped the fact that they were standing on soil hoary with history and which had seen a high degree of civilization when their forefathers were yet strangers to the new world. And to-day, in culture, in refinement, in education, in her

tween the United States and Mexico is important and is growing by leaps and bounds. I do not wish to stray too deeply into figures, but a few are necessary.

Imports of merchandise into the United States have grown from four and a half millions, (round numbers are "given") in 1874, to eighty-nine and a half million dollars in 1904.



THE WORKS OF THE GREENE CONSOLIDATED COPPER COMPANY AT CANANEA

During the same period exports from the United States to Mexico have grown from six million dollars to seventy-eight million dollars.

American capital has not been slow to seize the splendid opportunities for investment afforded by Mexico. United States Consul Barlow states that in 1902 500,000,000 American dollars were invested in railway, mining, and other enterprises in Mexico. Nearly all of this vast sum was invested within the last twenty-five years and at least half of it within five years. During the past four years (since 1902) it is estimated that \$200,000,000 more have been added. It follows that not only is Mexico a fertile field for investment, but that she must become in an increasing degree a customer of America, with wants and natural resources worthy the most careful investigation and study on the part of capitalists and business men.

With the inauguration of Porfirio Diaz, one of the world's greatest living statesmen, as president of Mexico in 1877, a new era dawned for the republic. The constructive ability of this man has few parallels in history. He found chaos and brigandage and poverty and ignorance. He has built a nation where life and liberty and property are protected, where law is respected and order maintained perhaps quite as well as under any other government in the world. He has builded better than most men know. After establishing order, he began to encourage active railway construction. Land grants and financial assistance were extended to various lines, the subsidies ranging from \$10,000 to \$20,000 per mile. At present a network of over 12,000 miles of railway connects all the leading towns and cities of the plateau and of the Gulf, extending also to the Pacific coast, while the mileage is being added to every day.

The government owns a controlling interest in the National Railway and other companies, and it is

thought that ultimately all the railway lines in the republic will be owned by the national government. A portion of these lines will be important links in the Pan-American railway system, which will finally connect all the South American republics with the United States.

In 1903 the first steel rails ever made south of Rio Grande River were rolled at Monterey. Structural iron is being produced in enormous quantities and within a few years Mexico will become great in her production of iron and steel. Within the last year vast beds of high-grade coal have been discovered as well as oil. At Hondo, near the Esparanzas mines, one company is now mining more than 150,000 tons of coal per annum. The scarcity of fuel has hitherto been a handicap to Mexican development and its discovery in enormous quantities marks an important epoch in her commercial history.

Next to railways, mining has attracted the greatest amount of capital. In approaching the discussion of this subject it is difficult not to be carried away with enthusiasm. Here is a land richer than that of Ormus or of Ind, rich in mineral wealth beyond the untold dreams of avarice.

The late Cecil Rhodes expressed his opinion on Mexico as follows:—"The richest mining countries in the world are Mexico, Peru and Bolivia—especially Mexico; and while Providence has cast my lot in an opposite section of the globe, I am not blind to the unison of opinions as expressed by scientists and experts that Mexico will one day furnish the gold, silver, and copper of the world; that from her hidden vaults, her subterranean treasure houses, will come the gold, silver, and precious stones that will build the empires of to-morrow and make the future cities of the world veritable New Jerusalems. I may not live to see the fulfillment of this prediction regarding Mexico, the land of 'mañana', but many of



THE CATHEDRAL AT GUADALAJARA

you will, and if you are wise you will avail yourselves of interests and positions in the rising tide of the world's wealth from the mines of that Aztec country in the western world."

A United States consular report says:—"The greater part of the Mexican peninsula has been rent by volcanic action. As a result the rocks have been impregnated with ore to a degree hardly equalled anywhere on the globe. For centuries Mexico has been known mainly as a

land of untold mineral wealth. The wide distribution of volcanic phenomena suggests the presence of valuable minerals everywhere. A line drawn from the capital to Guanajuato and thence northward to the mining town of Guadalupe y Calvo of Chihuahua, and southward to Oaxaca, thus cutting the main axis of upheaval at an angle of 45 degrees, will intersect probably the richest known argentiferous region of the world."

The historian Campbell says that

the total production of silver alone in Mexico since the opening of the mines, would reach \$4,000,000,000. These are figures beyond the comprehension of the human mind.

When we consider that the great mass of this wealth was mined by the most primitive methods, the results appear the more astounding. Take one illustration, the Santa Juliana mine at Ocampo. This is one of a group of 120 mines belonging to the Greene Gold-Silver Company. From this single mine have been taken, according to the government tax receipts, over \$100,000,000. It was worked to the depth of only 900 feet when its Mexican owners were forced to suspend work owing to their inability to handle the water encountered without pumps. The ore was mined by hand and carried on the backs of men up chicken ladders (notched poles), then placed on the backs of mules and carried one hundred and fifty miles across the mountains. To-day American capital and enterprise have built roads to these properties, and are introducing modern mining machinery and scientific methods, cutting tunnels that will tap the richer lower veins at such a grade that the mines will be self-draining, and the loaded cars of ore go out by gravity to the waiting mills at the mouth of the tunnel. If the old-time methods produced such results as those stated, what must be the result of twentieth century methods?

While there are rich gold deposits in Mexico, yet copper ranks second in value; indeed, Mexico is the second copper-producing country on earth. One of the greatest copper properties in the world is located at Cananea in the State of Sonora. It was originally prospected and worked by the house of Guam in 1580. The ore was taken out by hand, packed on the backs of mules to Monterey, thence shipped to Spain. But the commercial exploitation of these great ore deposits in a large way was left to Colonel W. C. Greene, the copper

king, one of America's greatest captains of industry, who is developing a commercial empire in the Southwest and doing for Northern Mexico what Cecil Rhodes did for South Africa. He has spent fifteen million dollars in developing the mines, erecting modern furnaces, concentrators, mills, etc., with rich returns.

At the present time the coal used in these Mexican mines is brought from Colorado and the timber from faraway Oregon. This is expensive and an enormous handicap to economic production; nevertheless such is the richness of the ore deposits that the mines are able to make large returns to their stockholders.

Within a few months a railway will be completed to the coal fields, and within a few weeks into the great Sierra Madre Lumber Company district which comprises millions of acres of virgin pine forests. Then not only will the mines of Mexico utilize



COL. W. C. GREENE, THE COPPER KING

her own coal and timber, but a new and most profitable source of wealth, lying hitherto unused for lack of transportation facilities, will be opened to the commerce of the world. But marvelous as is Mexico in her climate and in her untold wealth of mineral resources, these scarcely ex-



THE MARKET OF SAN MARCOS

cel her possibilities in agriculture, which in the last analysis must be the basis of enduring prosperity.

In this connection I quote from an annual report of the Director of the Bureau of the American Republics:—

“Frederick A. Ober, in one of his works, draws attention to the fact that Mexico’s shape on the map is that of a cornucopia, and calls the Aztec land a horn of plenty—a most appropriate simile. Nature has certainly showered her gifts upon the Republic with lavish hand. Her mines are practically inexhaustible, her forests rich in every variety of precious woods, her soil blessed with wonderful fecundity.

“Yet with all these natural conditions in their favour the Mexicans for more than two centuries delved into the bowels of the earth in search of silver and gold, and left the fields to lie fallow and the forests untouched, save where their products were needed for purely domestic purposes.”

Notwithstanding the fertility of her soil, Mexico is purchasing in the United States hogs, corn, meat and other necessities of life. The report already referred to continues:—

“The vegetable products of the country are varied in the extreme, owing to the diversified climate. Its productiveness is perhaps unsurpassed by any other country on the globe. The soil produces all the cereals and all the fruits of the United States and Europe, besides those properly incident to the tropics.

“Mexico, enjoying as it does a peculiar geographical situation and topography, may be divided into three agricultural zones or regions, which may be designated, according to their principal productions, as follows:—

“1.—The sugar cane and rubber region in the lowlands.

“2.—The coffee region in the temperate lands.

“3.—The region producing the European cereals in the central tablelands.

“The most fertile region, that which is almost spontaneously productive, is unquestionably the first, although it is the one which entails the most suffering, owing to the climate and the insects.

“In this favoured locality the soil is marvelously rich. In official reports to the Department of Promotion appear statements, which to those unacquainted with that portion of our continent would seem incredible. An agent of that department, reporting upon the lands in the southern part of the State of Oaxaca, states that on a sugar plantation in the district of Pochutla there have been found stalks of sugar cane 30 feet in height; that the tobacco plant, which grows wild there, has leaves 25 to 30 inches in length; that along the Tlaltepec River basin, in the same district, the coffee trees reach the height of large trees and produce 12 pounds to the tree. Certain wild rubber trees yield yearly 10 pounds of the dry substance. The vanilla plant grows wild also, and is excellent in quality. Three crops of corn can be taken from the same field in one year. Beans are so abundant that they are often sold in the neighbourhood at the rate of 25 cents per 100 pounds. There are 18 species of bananas and many kinds of palms, one of them yielding a much sought palm oil. One party imbued with great patience counted 5000 limes on one wild lime tree.

“Along the river bottoms of this well-watered region are millions of acres of land having a layer of humic soil 13 to 16 feet deep.”

In the temperate belt the lands are poorly watered and resort must be had to irrigation. The government, recognizing the vital importance of this matter, has enacted laws granting certain valuable concessions to individuals or corporations who will irrigate the land. These laws are so wisely framed that they not only provide for the irrigation of the land, but for the development of water power as well. In innumer-



THE PLAZA AT ZACATECAS

able places the topography is such that at minimum of expense mountain streams may be dammed and enormous quantities of water stored both for power and irrigation purposes. The value of this asset in the future industrial development of Mexico can hardly be overestimated.

Stock raising in Mexico is an important and profitable industry. The northern States of Mexico are admirably adapted to cattle raising. The climate is genial and the lands are generally well watered and produce most nutritious grasses.

He would be a bold man indeed who would undertake to set bounds to the future development of this republic of the South. In northern and western Europe an area equal in extent to Mexico supports 180,000,000 people. In natural resources Mexico is as well endowed, and in some period of the future she may contain a population as great.

In some circles not well informed, a doubt is sometimes experienced as to the stability of the Mexican Government. The facts are that life, liberty and the rights of property are quite as well, if not better, protected in Mexico than in the territory north of the Rio Grande.

I cannot do better on this subject than to quote from an official document issued by the United States Department of Commerce and Labor:—

"It is often assumed that the present reign of law in Mexico is bound up with the life of Porfirio Diaz, and that when he dies there will be no strong hand to seize the helm of state. The mistake lies in the assumption that the present government is a dictatorship. It is neither this nor even an oligarchy, but simply the rule of a class, to wit, the educated class. If in all countries the essential requisite of a good system of government is that it shall place the power in the hands of the most intelligent and honest, this is especially true of such a country as Mexico, where so large a percentage

of the population at present is utterly illiterate and unaware even of the existence of the problems of civilization.

"Fortune has favoured Mexico, therefore, in endowing it with a sufficiently numerous class of gifted, enlightened, and public-spirited men, trained in the hard school of the French invasion, chastened by long national humiliation, inspired, it must be added, by the spectacle of law and order and unparalleled prosperity in the neighbouring republic, and determined, under the guidance of a resolute chief, to procure the same blessings for their country. Though the vigorous influence of the chief executive pervades all the departments of government, it is nevertheless a fact that the details of administration are mainly the work of his enlightened associates. When he dies or retires he will leave a school behind him.

"Five factors, in particular, serve as a guaranty of future stability:—(1) The vast network of railways now extending over almost the entire republic; (2) the immense foreign investments; (3) the great increase in popular education; (4) the disappearance of class privileges; (5) the great increase of prosperity.

"Formerly, if a revolution broke out in a remote district, the government had almost no means to convey troops and material to the disaffected locality; now it can do so in a few days. Revolutions would at present be hampered in every direction by the necessity of respecting foreign property, for fear of provoking foreign intervention, the very name of which evokes dismal memories.

"The educational system being almost entirely under State control, the rising generation is being imbued with the necessity of law and order and national union as conditions to progress and individual prosperity. The old fomentor of revolutions, the reactionary party, having lost its privileges and become thoroughly discredited by the invitation it ex-

tended to foreign invasion, has disappeared. Finally, as 'El Economista Mexicano' well remarks, Mexico lived in a state of war for lack of work; with the advent of work, public tranquility descended on the land. For work meant the cessation of hunger, and the end of hunger meant the end of revolutions."

The foundations of the Mexican Government are as secure as those of the rock-ribbed Sierra Madres. They are based on civil liberty, order, education, progress, and justice to all men.

With a climate equal to the best on earth, with a soil as fertile as the famous valleys of the Tigris and the Nile, with vast forests yet untouched by the hand of man, with mountains of iron ore, the wonder of the world, with coal fields that promise to rival

in extent those of any other country, with unused water power in her mountains enough to drive the commerce of a nation, and above all and beyond all and surpassing all, vast deposits of precious mineral wealth awaiting but the magic touch of modern man to flow in streams of molten copper and shining silver and yellow gold into the coffers of civilization, with a wise government standing with outstretched hands to welcome capital and enterprise from every quarter of the globe,—with a combination of all these fortuitous facts, must it not follow as surely as the night the day that before the sun of the twentieth century has reached its meridian, the Republic of Mexico will be counted as one of the greatest and richest nations of the earth?



ABSOLUTE SAFETY AT SEA

IN A 1200-FOOT, 170,000 HORSE-POWER STEAMSHIP

By Joseph R. Oldham, N. A.



PROBABLY there never was a fatal disaster which was not attributable to carelessness, at least in some degree. The boiler that burst was of bad or corroded steel, was of faulty design, or was negligently worked. The shaft that gave way was of weak proportions or of bad material, or was sub-

jected to undue stress, which should have been anticipated. The captains who run their steamers ashore and who collide with one another in a fog come to disaster through running at too high a speed, through neglect of the proper use of log and line, and other instruments or devices which should be at their disposal.

Moreover, I incline to the opinion that warning is always given of impending disaster, though men are not always learned or alert enough to perceive the admonition. The bursting boiler gives signs of distress either to the eye or ear before it explodes. The shaft that breaks exhibits flaws as a warning or indicates a defect if specifically weighed. The strained or weakened ship always exhibits signs of distress. The mysterious current which sweeps the vessel from her course and the approach of an unseen vessel may be ascertained if due care be taken in time, and precautions can be adopted to avert disaster.

I remember well a great steamship company who, year after year, lost a large and costly mail steamer on the same course,—for either seven or eight consecutive years. Most of those vessels were lost in much the same manner. I also remember well another great company operating steamships in a similar trade, which for a most remarkable epoch of about forty years never lost a ship, a passenger, or a letter. Is it conceivable that an unavoidable chapter of “accidents” attended the former ships while the goddess of good fortune guided the latter in safety during a much longer period? Would not the more logical conclusion indicate carelessness or inexperience associated with the construction or equipment of the ships, or else carelessness or inefficiency in handling them in the former case, while general and particular efficiency in construction and operation was the dominating factor productive of a most exceptionally favourable record in the latter case?

This, then, would seem to lead to the conclusion that with careful design and sound construction, coupled with cautious and capable navigation, an ideal ship should carry her passengers free from peril when crossing even the most stormy ocean.

When considering the design and construction of some half a dozen iron mail steamships which came to sudden destruction on the rocks or through collision, I cannot call to mind a single instance of a great disaster to a vessel provided with a continuous double bottom or with a double shell throughout, as embodied in the structure of the “Great Eastern.” Though this essential feature

of a passenger ship might not have averted fatal disaster in all the cases referred to, it has yet to be proved whether this fundamental element of safety in ship construction would not have kept these ships afloat for a sufficient time at least to save the lives of the passengers.

The exact cause of the loss of hundreds of missing ships it would be difficult to show, but I have in mind three distinct classes of ships which were lost at sea with hundreds of sailors on board, and of which we know the cause of disaster. One was a low-freeboard monitor which was fitted with large topsails, like a sailing vessel. She capsized either through an error in design or through one in seamanship in carrying sail at that time. The second vessel capsized when grain-laden in spite of the expostulations of the mate and the grumbling of the crew at the foolhardiness of the master in carrying too much sail, he being anxious to cross the line that fatal night. The third disaster was caused through leaving gun ports open with all sail set because of being nearly in port. These typical disasters all resulted from inexperience or carelessness. Great advances have been made, however, of late years toward absolute safety at sea.

During the year 1881, for instance, not fewer than 1338 British vessels, with 3580 lives, were lost at sea. Though British steam tonnage has increased threefold since that date, the loss of life in British vessels last year was but one-sixth of that of 1881. In other words, in those days one life was lost for every 800 tons. Last year the loss was one life for every 20,000 tons. If this improvement should continue, it would not be many years before loss of life at sea would cease altogether, and if efficiency in the handling of ships should continue to advance as rapidly as the construction is improving and safety devices on sea and land are multiplying, an ocean voyage with absolute safety would soon be assured.

About eight years ago there appeared in CASSIER'S MAGAZINE a description by me of a ship 1200 feet long which, I said, was due, according to geometrical progression, in one-third of a century from that date. I now give a few more particulars of that vessel.

It is as clear as ever to me that in twenty-five years from this date a steamer approximately 1200 feet in length, 125 feet in breadth and 81 feet in depth will be afloat. This vessel will be designed for a reserve merchant cruiser. She will have a strong protective deck and a complete double shell from keel to structural deck; her top sides externally will be of nickel steel, while the inner shell will be strongly built on the cellular system with steel of exceptional ductility to permit of a great degree of buckling without a fracture.

The bottom will also be sheathed with teak wood, after the manner adopted by the Russian Admiralty, which makes a strong connection without perforating the bottom plating. The sheathing will permit of "coppering" to avoid fouling and will add greatly to the safety of the ship in the event of grounding, as such a wooden cushion has often saved steel plates from fracture.

The displacement will be 75,000 tons at 40 feet draught of water; gross tonnage, 67,500; passenger accommodation, 6700. I have given this vessel a cut-water stem and bowsprit not because "it looks nice," but because "it is nice."

With small vessels, I have always found the fore rake with figurehead and bowsprit contribute to seaworthiness by keeping some water off the decks in a head sea. Moreover, this form of bow does less injury in striking another vessel; therefore, though this form may not be of great use in the present instance, I have adopted it because in a general way "it is nice."

There will be two longitudinal and twenty-four double transverse bulkheads extending from the bottom to

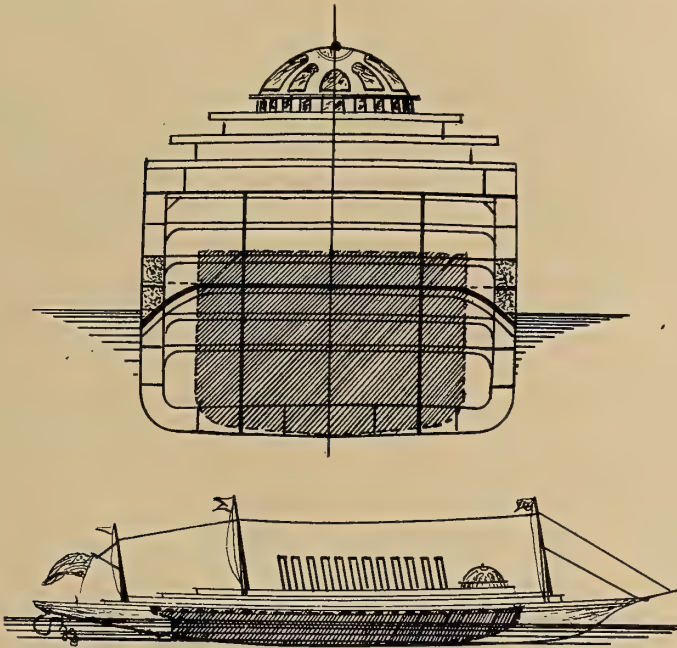
AN UNSINKABLE STEAMSHIP

21

the structural deck, forming coffer dams, and without any doors or port openings, elevators and stairways being arranged in every compartment. The speed will be 30 knots an hour, secured with improved turbine engines of 170,000 H. P., driving five screw propellers.

There will be 60 boilers with 400,000 feet of heating surface, and 12 smoke stacks. A special feature of the general arrangement will be extra large pumping power, with boilers

more than an ordinary vessel of like tonnage would cost. To make this up and pay the cost of a superior crew, an extra charge for passage of nearly \$25 per head might be necessary. I think it is more than probable that, with the growing popularity of the trip across the Atlantic, passengers would always be forthcoming who were willing to pay an extra \$25 to secure absolute safety at sea in a protected cruiser with a speed of 35 miles an hour.



COMPARATIVE DIAGRAMS OF THE CUNARD LINE STEAMSHIPS "LUSITANIA"
AND "MAURETANIA," THE LARGEST SHIPS NOW AFLOAT, AND
THE NEW MAMMOTH STEAMSHIP HERE PREDICTED

and pumps placed well above the load-water line. I propose that certain compartments containing 2500 tons shall be kept full of water, so that in the event of grounding these compartments could be emptied in 12 minutes, which would in most cases of grounding enable the ship to float off, as 2500 tons would represent one foot draught of water.

The estimated cost of this steamer is \$17,000,000. This is 25 per cent.

The loss or destruction of a ship at sea is always due to one of the following causes or defects, or to a combination of these:—

1. Carelessness or inexperience in designing or constructing the hull or machinery.
2. Carelessness or inexperience in the loading or stowage of cargo.
3. Carelessness or inexperience in navigating or operating the ship.

If these causes can be eliminated,

or indeed partially eliminated in some instances, no voyager should be lost at sea. As regards loss due to wind and weather, I may say that no large good ship, well found and well handled, should ever succumb to the elements, however hard the wind may blow or the sea may roll.

The sea is a gentle creature, and there is now no safer place during a hurricane than a good ship in deep water. On land the cyclone may sweep away houses, and the earthquake destroy cities, but no wind or sea can harm the good ship well loaded and well manned, if she be kept clear of shallow water.

No other proof, I take it, is needed in confirmation of this statement than to name a score or more of vessels which I have seen after they had braved the winds and waves continuously for half a century without vital injury. Among these I may name:—The "Great Britain," the "Mooltan," "Poonah," "Tiber," "Orontes," "Montague," "John Bowes," "Michigan," and "Bengal."

It is inconceivable that all these ships were at all times operated with care by experienced seamen; hence it appears that the winds and waves cannot destroy a good ship, even though she be at times carelessly navigated. So the ideal ship of great proportions to which I now refer may be considered absolutely invulnerable when assailed by storm and tempest.

Regarding the second danger referred to, namely, that of improper loading or stowage of cargo, this may be guarded against by the officers watching the loading, in vessels which carry cargo, and by the increasing practice of inclining the ship and noting the amplitude of roll in connection with stability diagrams. With such safeguards there is no danger of a modern steamship capsizing at sea.

The danger of collision with another ship or with ice is not likely to occur with the exercise of reasonable care and skill in using modern appli-

ances, but should such a calamity happen as a collision with such ships as I am now considering the consequences would be serious though not necessarily fatal.

Let me now briefly consider the most serious situation in which a ship could be placed, namely, that of coming into violent collision with another similar steamer at high speed. A few years ago I remember an eminent counsel detaining the court in an admiralty suit for a considerable time while I made it clear to him that momentum is not kinetic energy. As a simple illustration of the latter, suppose a stone be thrown up, perpendicularly, into the air; the energy communicated to it, is at first purely kinetic, but as it ascends its kinetic energy is continuously changing into the potential form, until it has reached the turning point, where, for an instant, it is without motion. Its kinetic has now been transformed into potential energy.

The stone has not altered its state, though it is now without motion as it was when lying on the ground, and yet it now possesses more energy than it then had; it has in it all the energy due to its elevation. This immediately begins to be changed again into kinetic energy as it gains acceleration in its fall. This energy, on impact of the stone with the earth, is transformed into heat; the work of breaking the ground, friction and the production of electricity, all are forms of mechanical energy, and together they will be equivalent to the amount of energy due to the elevation of the stone.

In the steamer moored at the dock with steam up ready for sea, we have examples of that form of energy that is called dormant, or latent, or potential. When she proceeds to sea and gathers way, that potential energy becomes kinetic.

The work done by a body may be expressed thus:—

$$\frac{\text{Weight of a moving body} \times \text{The square of the velocity in feet per second}}{64.4} = \frac{\text{The kinetic energy of the body expressed in foot-pounds}}{64.4}$$

Or the living force of such a vessel as I am here considering may be ascertained by the expression:—

$$\frac{1}{2} W V^2$$

Substituting g numerals in this formula, we have:—

$$\frac{37,500 \times 2500}{32} = 3,242,200 \text{ foot-tons}$$

Thus the living force of this steamer at full speed is equal to practically three and one-quarter million foot-tons.

If this ship were struck by an ordinary vessel, she would scarcely feel the shock, but if she struck another ship the consequences would be serious—to the other ship, as all the energy of forty railway trains speeding at 60 miles an hour could not stop her. The energy developed by all the guns of five "Dreadnaughts" would not check her speed. It is here that the most imminent danger exists.

Imagine, that by a combination of carelessness and recklessness on the part of two commanders and their officers, two such ships did come into collision at full speed. The destructive result would be beyond calculation; no mathematical investigation could show exactly the result of such mechanical work, but as there would be two complete shells, specially designed for such an emergency, 20 transverse coffer dams formed by 48 solid bulkheads and 2 longitudinal bulkheads, all absolutely intact from the keel to the structural deck, thus forming 147 main compartments, exclusive of the cellular bottom and sides, it may reasonably be concluded that the great ship would not founder.

As nothing approaching the force of the impact of two bodies representing a combined energy of over six million foot-tons has ever been known on earth or sea, the claim of immunity from total destruction of these structures may not be capable of proof, but I may say, after having investigated thousands of ship colli-

sions, that absolute safety at sea might still be assured, notwithstanding the extreme situation of peril here admitted as a possibility in ocean navigation.

The last situation of extreme peril to be treated of is that of running onto a submerged rock or a rocky shore. In this case the lower bottom might be punctured almost from bow to stern and the upper bottom might also become fractured in some parts; but through the great strength of the hull and the reserve buoyancy secured by hundreds of watertight compartments, coupled with pumps, placed above water, and capable of discharging 12,000 tons an hour, the great ship would remain above water for several days at least, to permit rescue from the shore or from another vessel. But in any event no passengers would be lost, as 12 large motor life boats and 50 rowing life boats, manned by crews of proved efficiency as boatmen and swimmers, could take care of all the lives. In addition to this, a part of the outfit would consist of large balloons or air-ships capable of carrying a line on shore or rendering other assistance.

The danger from destructive fire need not be seriously considered with the provisions made to subdue it, as the staterooms and division bulkheads would be of metal and asbestos. The little wood in the structure would be as nearly as possible non-inflammable, and not a ton of cargo and only a limited amount of baggage would be carried.

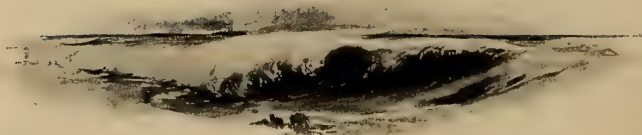
The logical conclusion from the foregoing argument is that life will be almost perfectly safe at sea in my ideal ship of a quarter of a century hence, and though that ship may appear too large and costly for private enterprise, and the life-saving devices too elaborate for financial success, I may point out that the structure includes all the basic elements of a most powerful protected cruiser, which features might call forth national aid to defray the first cost and assist in maintenance.

Though the advancement in ship design and construction depicted in these pages may appear drastic as the progression of a third of a century, I may point out that, considering the facilities and resources of the nations, the advancement in ship construction during the last third of a century was no less rapid than the next epoch will be, should my original prophecy of 1898 be realized.

If in the year 1875 any one had ventured to predict the coming of a steamer nearly 800 feet in length, of 70,000 H. P. without a crank shaft, and equipped with wireless telegraphic apparatus which, it is said, will automatically stop ships should they approach one another in a fog, and other wonderful safety devices, he would have been accused of romancing, and yet I verily believe

that the recently launched turbine steamships "Lusitania" and "Mauretania," of the Cunard Line, represent as great an advance over the "Germanic" of 1874 as the great steamship I have outlined does over the "Lusitania" and "Mauretania."

In conclusion, I may say that if the combination of carelessness and recklessness, allowed only for the sake of argument to bring about a collision at high speed of two such ships as I describe, be omitted, as being improbable in the highest degree, I may close this investigation with the comforting assurance to the timid voyager and his anxious friends on land and sea, that absolute safety at sea is within the bounds of practical achievement, before such vessels as the "Lusitania" and "Mauretania" become worn out or obsolete.



ELECTRICITY IN THE HOME

By H. W. Hillman

Mr. Hillman, who has under his care the electric heating department of the General Electric Company, at Schenectady, N. Y., lives, with interesting appropriateness, in a thoroughly equipped electric house, and it is this to which he refers in the following pages. It has latterly been made the subject of half a dozen magazine articles, but in none of them have all the advantages of domestic electric service been emphasized to the full; hence this additional contribution by Mr. Hillman himself, who naturally is best qualified to express himself on the subject.

To what Mr. Hillman says, it is of interest to add here that in planning the house Mr. Hillman had two sets of specifications prepared, one including the cellar excavation for coal and wood storage under the entire house, and a kitchen range with its inevitable chimney. The other specification was with only half the cellar excavated, the other half of the foundation going down only to the frost line, with no provision for a kitchen range and kitchen chimney, but including the installation of heating and cooking circuits and outlets in addition to the lighting circuits. When the estimates were examined it was found that the difference in cost between the first and second plans was so much in favour of the second, that the amount saved was more than sufficient to purchase the entire electric kitchen equipment and all the other small electric utensils used throughout the house. The extra cost of wiring was about \$125, or less than 1 per cent. of the total investment.

In connection with the present article also it may be interesting to refer to the one in the June number of this magazine, entitled "Extending the Uses of Electricity." This told in a more general way of what electricity was ready to do toward lightening the burdens of domestic service.—The Editor.



THE experience in my home during the past three years with electrical devices has led me to think over very seriously the reasons why the people in general consider the subject so favourably, and why the devices are so popular. A household device might be especially convenient,

and yet fail to attract the attention of the housewife, due to a high initial cost; or it might possess both essential features of convenience and low initial cost, and yet a high operating cost would make it unpopular for general household use with many people.

In my opinion, the prime reason for the great popularity of household electrical appliances is found in connection with their excellence of engineering design, which has been particularly marked during the past two years. An electrical engineer who is master of the art will con-

sider all phases of a subject before submitting a design of an article to be manufactured and commercially introduced. Such has been the case in regard to the electrical appliances used in my home. It was necessary to have the initial cost of the articles compare favourably with old-style utensils used with coal and gas ranges, and then, with a reasonable operating cost at the average rates of charge by electrical companies throughout the country, the problem was solved.

An illustration of these two points, —low operating cost and low initial cost,—may be interesting and instructive. It is a matter of common knowledge that in the operation of boiling eggs, either with a gas stove or a coal stove, a small quantity of water, say a pint, is placed in an ordinary cooking utensil, either on the lid of the stove or over a gas flame. Several minutes are required to bring the water to a boil, and then the eggs are placed in the dish for three, three and one-half, or four minutes, varying with the desire for a soft, a medium, or a hard-boiled egg.

In comparison, the electric egg

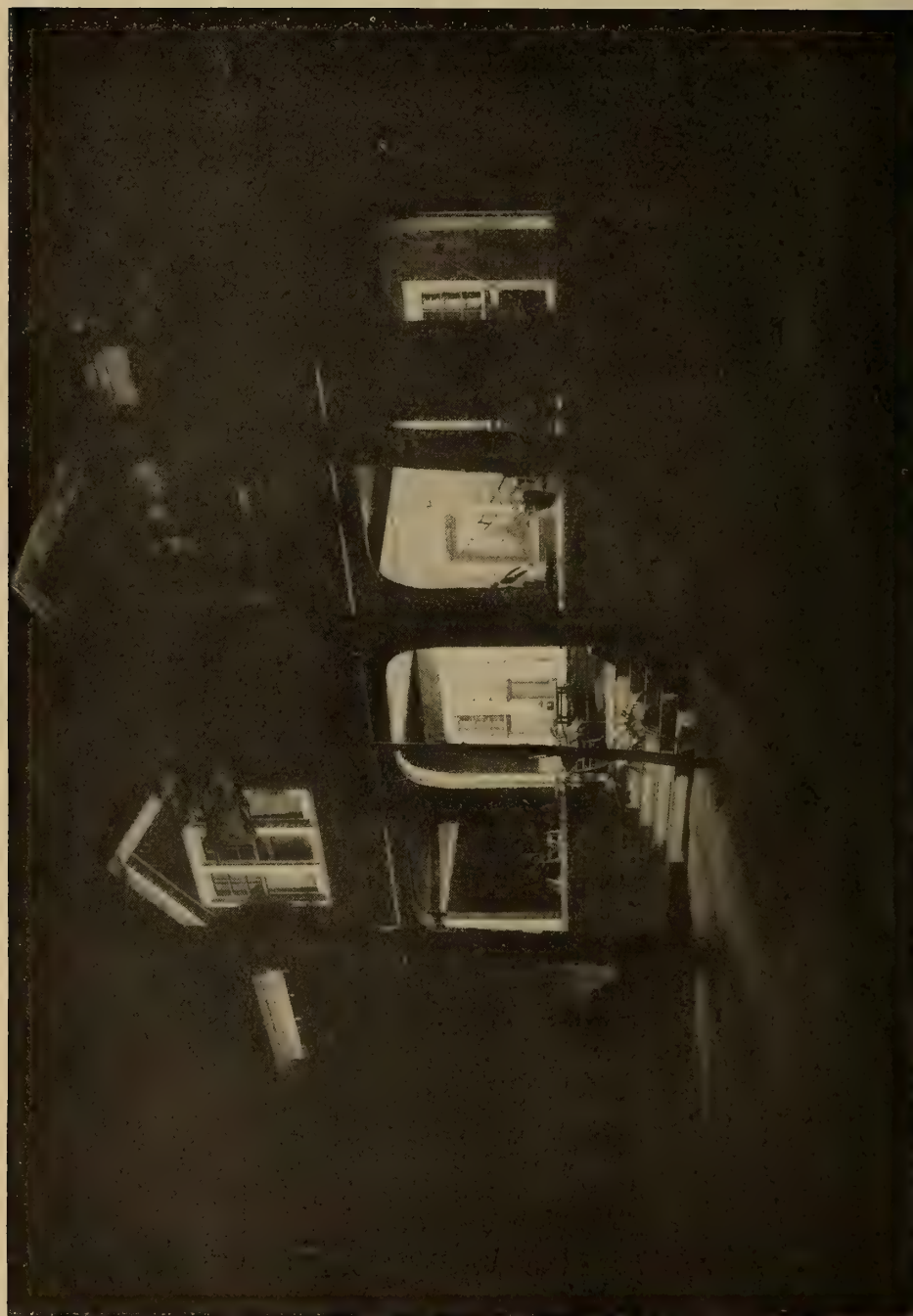


FIG. 1.—REPRODUCTION OF AN EVENING PHOTOGRAPH OF MR. HILLMAN'S HOUSE, TAKEN BY THE LIGHT OF A TUNGSTEN LAMP ON THE PIAZZA



FIG. 2.—ON THE PIAZZA OF MR. HILLMAN'S RESIDENCE. AN ELECTRIC RADIATOR, A CIGAR LIGHTER, AND A MESSAGE MOTOR HERE DO SERVICE

steamer requires forty-five seconds for a spoonful of water to arrive at a steaming point; the cover is then raised, the eggs are dropped in, and a three, three and one-half, or four-minute egg is steamed. The total time, therefore, is three minutes and forty-five seconds for a soft-boiled egg, or less than half the time which has been commonly required when boiling eggs in the old way.

I claim that this application of electricity, as suggested by a thoughtful engineer, represents a principle of economy that affects time and labour in a way to make the experience with electricity in my home a success. The same principle is utilized in cooking potatoes and cereals. The same principle also is, used in connection with heating a baby's food, where time is a very important factor. Expense is also a factor when considering that such food may be required six or seven times a day, or about 2000

times a year. This point of economy in time and expense is mentioned simply as an illustration of many new applications of electricity, bringing the cost of operation down to such an insignificant sum that people are naturally very much attracted to the devices.

Let us suppose that the old way of accomplishing such results could be changed, and that all kinds of dishes could and would be redesigned so as to utilize the same principle of cooking by steam instead of boiling water. Even then the argument will not be a forcible one, because there are so many operations by electricity for household use where the cost is already so small that a little further economy of gas or coal would not overbalance the convenience which the electrical devices possess, compared with coal and gas appliances. In other words, the engineer who discovered this point of applying electricity in such an economical way has brought the

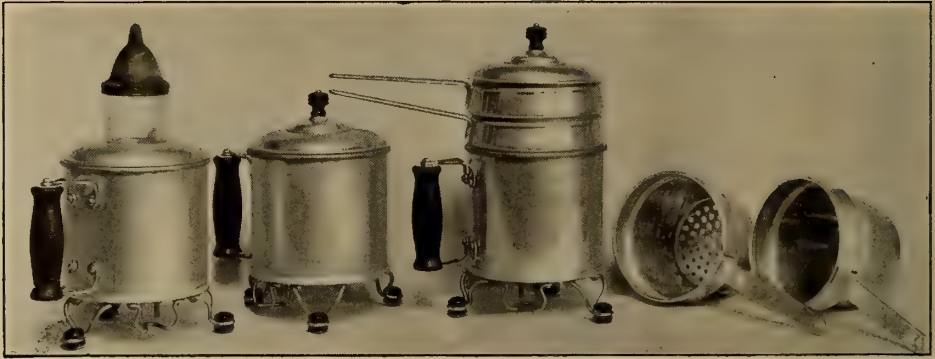


FIG. 3.—A FIVE-COMBINATION ELECTRIC COOKING DEVICE

cost of operating down to a point well within the means of many classes of people, and changed the condition of things as compared with what they were a few years ago.

At this point the question will be asked, if only a spoonful of water is used, what will happen should the water evaporate, and the device be left operating dry by mistake? The same engineer who conceived the idea of cooking by steam electrically, also conceived the design of manufacturing electrical devices so as to be indestructible. If they are left operating dry by mistake, the dish is not injured, nor is the surface on which it rests, nor the heating element. On the other hand, the ordinary cooking utensil, placed over a gas flame, or on a coal stove, operating dry by mistake, would be injured, so as to require replacement. In other words, while the electrical engineer has given great thought and attention to this subject in connection with the new electrical appliances for cooking, evidently the same careful attention has not been paid to all other utensils used with gas and coal stoves. Therefore, to be competitive with electrical articles, new developmental work must be started, and time will be required before the same results can be accomplished with all the old-style cooking utensils.

As a user of electric household utensils exclusively, I am convinced

that the above-mentioned principles represent important, far-reaching features, and as these new ideas become generally known among households, it is plainly to be seen why the subject is so interesting to the public.

The above explanation will also show why my monthly electricity bills, covering a period of two years, have been so low. The average monthly bill for the past twenty-four months was \$6.69, at a price of 5 cents per kilowatt-hour, with a family of five. During the past year, a great many homes have been fitted up with similar appliances, and under the same conditions, with the same price of current, the bills have been about the same.

In regard to initial cost of devices, great ingenuity has been exhibited in their design. The egg steamer, for example, is known as a five-combination dish. It is the equivalent of five dishes, or performs five different operations. When considering the average household work at different hours of the day, it will be seen that the same dish can be used practically for the various operations. It is not a matter of theory, but represents a practical feature of the article as a water heater, an egg steamer, a cereal cooker, a potato steamer, and a baby food warmer. This device performs the five operations, and yet the initial cost is only slightly higher than it would be as a water heater, or one device.

This is simply one illustration of many of such combination devices which economize in first cost. Space will not permit of mentioning the various articles which are so designed. Too much stress cannot be laid upon the two points mentioned,—economy in operation, and economy by having combinations of many devices. They have been the means of popularizing electric household devices with rates of charge commonly made for current by most of the electric central stations.

late in September and early in October the average temperature is not such as to require starting the central heating system in the house. Still it is frequently done; then the weather changes, and the fire is allowed to go out again. The cost of operation must necessarily be high when operating a furnace, or boiler, for a day or two at a time instead of continuously. With the electric auxiliary system, quick heat in the bathroom for fifteen minutes in the morning or at night is sufficient, and not

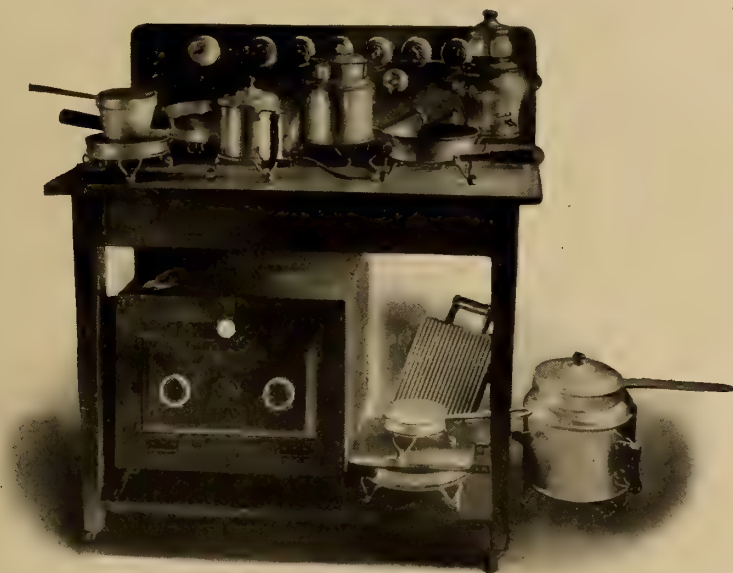


FIG. 4.—ELECTRIC KITCHEN CABINET AS USED IN MR. HILLMAN'S RESIDENCE

The "ready-to-serve" feature has impressed us greatly in our residence. If a quick meal becomes necessary, there is no question whether the coal range is ready, or the fire is low, but the electric frying pan is immediately available; the meat broiler and the griddle-cake cooker are quick devices, and emphasize the "ready-to-serve" principle. I have used to advantage four luminous radiators as an electric system of heating during spring and fall seasons for auxiliary or supplementary heat. It is well known that

expensive. A little heat for a half hour in the morning in the breakfast room is very desirable, yet not expensive. After three years' experience with these electric heaters, I should dislike very much indeed to get along without them and depend upon the central-heating system in the house for heat during the early spring and fall seasons.

To my knowledge, there is no steam or gas motor which is convenient and easy to use for a massage operation, while the electric massage motor is beautifully de-



FIG. 5.—AN ELECTRIC LUMINOUS RADIATOR

signed for such work. It can be placed upon the socket in the bath-room, bedroom, or anywhere in the house. It weighs but 4 lbs., can be handled conveniently, is designed with various massage tools, and the expense of operation is negligible.

I do not remember ever having seen a household lighter for cigars, cigarettes, or pipes, and do not believe that such a device has been designed for convenient use with gas. However, I have in my house several electric cigar lighters, which are exceedingly convenient, and attract

much attention from visitors who enjoy the inspection of our electrical devices.

I do not remember ever having seen an attractive ladies' gas or stove iron for use in the sewing room in connection with light work such as ironing handkerchiefs, linen, etc., or for quickly pressing trousers, or for use in connection with a silk hat. Hence the small, 3-lb. electric flatiron is a household necessity. So much evidence has been offered during the past two years to prove this point that I will not dwell upon the popularity of this device as a domestic convenience.

From a careful consideration of the above, one gets an impression that the electrical engineer has been devoting much thought and study to the use of electrical devices in the home, and the results have been most excellent. It would seem, on the other hand, that gas and steam engineers have not attached much importance to the subject, or else household devices for general use with gas and steam heat have been difficult to design, and perhaps the expense has not been warranted. At any rate, the fact remains that the engineers of the electrical industry have taken the lead, and are deserving of much credit for the attractive designs presented to the public. Evi-

dently their work has only just commenced, because I frequently hear of new articles being developed which leads me to believe that electric applica-

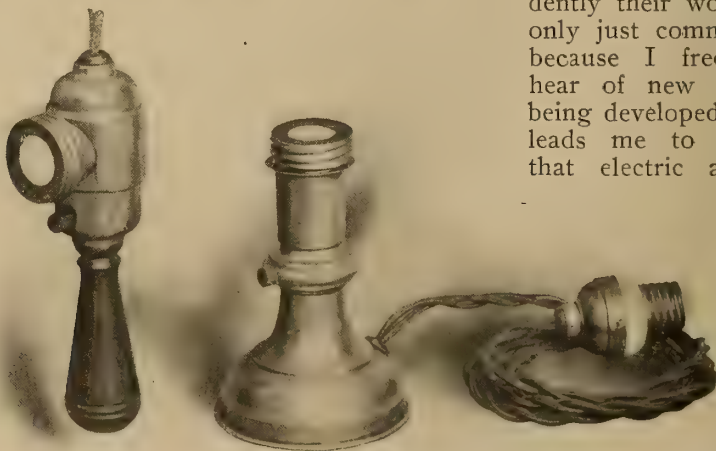


FIG. 6.—ELECTRIC CIGAR LIGHTERS



FIG. 7.—A PART OF THE BATH ROOM, WITH ELECTRIC RADIATOR, MASSAGE VIBRATOR AND WATER-HEATER FOR SHAVING



FIG. 8.—AN ELECTRIC COOKING AND BAKING TABLE, DESIGNED FOR A LARGER FAMILY THAN THE ONE IN FIG. 4

tions in the home will be even more fully realized than we have dared to believe heretofore.

The wiring plans of my house are rather interesting. In many ways they may be helpful to others desiring to take advantage of the conveniences mentioned. In connection with a new house being erected, an easy opportunity is afforded for wiring with two sets of circuits, one circuit for lighting devices and an-

other for heating devices. Architects and wiring contractors are becoming so well posted on the subject of electricity in the home that it will be an easy matter for the owner of a new house to secure good advice on the subject, and have plans made up by the architect accordingly. If a \$10,000 or \$15,000 house is under consideration, the extra cost of wiring for a separate heating circuit should not be more than \$150,

that is, in addition to the cost of the lighting circuit, and as this represents such a small percentage of the total expenditure, many owners will desire to have both circuits.

In connection with a \$3000 or \$4000 house, it is a very common matter to wire for electric lights; but by giving the subject a little further attention with your electrical contractor, and the architect, it is possible to arrange outlets for lighting socket heating devices at very little extra expense. Such receptacles would be taken off from the lighting wires in a very simple manner. The cost of operating later, at lighting rates, would not be large, for the reason that the electrical devices which will be used on such a circuit consume only a small amount of electricity, and are generally used for only short intervals. They would comprise, for example, the chafing-dish, the coffee percolator, heating pad, cigar lighter, shaving mug, curling iron, baby milk warmer, small frying pan, and many others.

Electricity in the home has an important bearing upon the kitchen of the house; especially is this true where the kitchen is small. Many articles have been written about desirable kitchens, and almost always the recommendation is made that any up-to-date housekeeper should have a gas stove, in addition to the coal range,—also, a goodly sized kitchen table for the convenience of the cook. It is easy to imagine how a small-sized kitchen would be very much crowded if such recommendations were followed. On the contrary, in recommending an electrical outfit for an up-to-date kitchen, the greatest economy in space is secured, as well as maximum convenience. In connection with the several classes of tables shown in this article, particular attention is called to the kitchen cabinet. In building a small house for two persons only, it frequently occurs that a small-sized kitchen and a small-sized pantry are

preferred. In such a case, the kitchen cabinet takes the place of coal range and gas stove; a stock of all the cooking material is kept in the cabinet, and it also answers the use of a table, so that it is practically the only piece of furniture in the kitchen except chairs. Fig. 4 shows a plain type, small table for a small-sized family; Fig. 8 shows a large table for use with a large family.

An incandescent light is placed at the front of the table so as to indicate that the current is on. Some of the first experiences in our house without this indicator light were annoying, and it is considered to be a very convenient improvement.

The fuse block will be noticed also on the back-board. If a fuse blows for any reason, it is exceedingly convenient to replace the plug, and this makes a very simple arrangement.

Below is given a list of desirable articles for small and large-sized families:—

SMALL-SIZED FAMILY

Seven-inch frying pan.
Two-quart cereal cooker.
Oven.
Two-quart teakettle.
Double quick broiler.
Grid.
Coffee percolator.

LARGE-SIZED FAMILY

Ten-inch frying pan.
Four-quart cereal cooker.
Kettle.
Oven.
Double quick broiler.
Grid.
Coffee percolator.
Four-quart vegetable boiler.

Such outfits can be purchased complete for about \$60 and \$30, respectively, thus comparing favourably with combination coal and gas stoves or large-sized ranges.

It would seem almost unnecessary to say anything about electricity for light. At the same time, great convenience and small lighting bills can be secured by paying particular attention to plans for wiring when the house is being built. On the lower floor of my house there are no chandeliers, but arrangements for attractive ceiling lighting, using the reflector type of lamps. The ceilings are covered so that the lamp

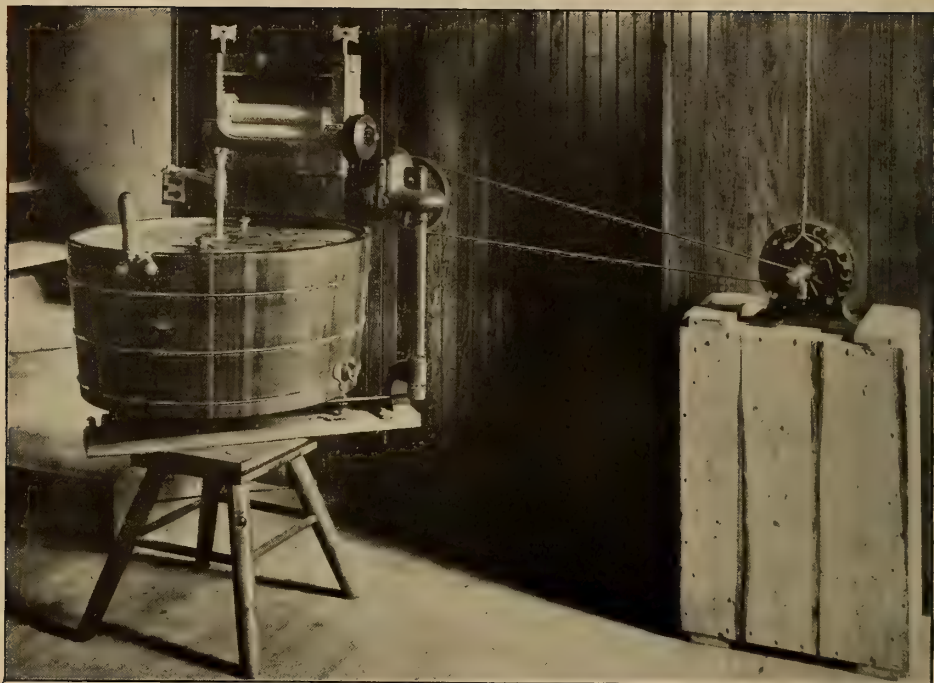


FIG. 9.—MOTOR DRIVING A WASHING MACHINE AND WRINGER IN MR. HILLMAN'S HOME

reflects its light at an angle of 45 degrees, giving the best illumination on the dining room table. Eight lamps in all are installed in this room, and the switches are arranged so that one lamp can be switched on for general lighting; two or four lamps for good illumination, and the entire eight for a brilliant display.

In the living room ten lamps are installed, and these are of the high-efficiency, $2\frac{1}{2}$ -watt type which have recently been commercialized. By paying particular attention to improvements in lighting in this manner, I have secured even greater illumination in some rooms, or lower costs for the same illumination.

One of the most recent, and greatest, improvements in electric lighting is shown in connection with one lamp which I have in operation on the front piazza. It is known as the "Tungsten" type, and is remarkable for its very high efficiency. The illumination from this one lamp is

such that it has been possible to do very fine embroidery work for several hours in the evening under its rays. Fig. 5 has been reproduced from an evening photograph, and gives a fair idea of the illumination obtained.

As people generally have, for a long time, been well posted on the subject of electricity in the home, for light, and are generally taking a keen interest in educating themselves in regard to electricity for heating operations, it is also well at the same time to know about the use of electricity for power in the home. The sewing-room electric motor is probably the most convenient of all. It is becoming universally used; every up-to-date electrical company advertises it in their monthly bulletins, sent to prospective users, and it was in this way that we were led to the use of the motor in our home. It can be operated for an hour for about a cent, and its first cost will vary from \$10 to \$12, depending upon condi-

tions, the type of sewing machine, etc. The electrical company will install it and in many cases offer the motor on the installment plan, to be paid for monthly,—a small portion in addition to the regular monthly electric bill.

A small motor in the laundry or work shop is exceedingly convenient, and at the same time represents a simple installation. It can be used for operating the washing machine, the wringer, the buffer for cleaning

tached to it, as it is a permanent installation thereafter, and no repairs or renewals are required. The amount of electricity required to operate it is so infinitely small as to be negligible.

Before closing, it would be interesting to call attention to the use of electricity in the home by referring to the increasing numbers of electric automobiles which are being used. This increase is due in no small degree to the successful intro-

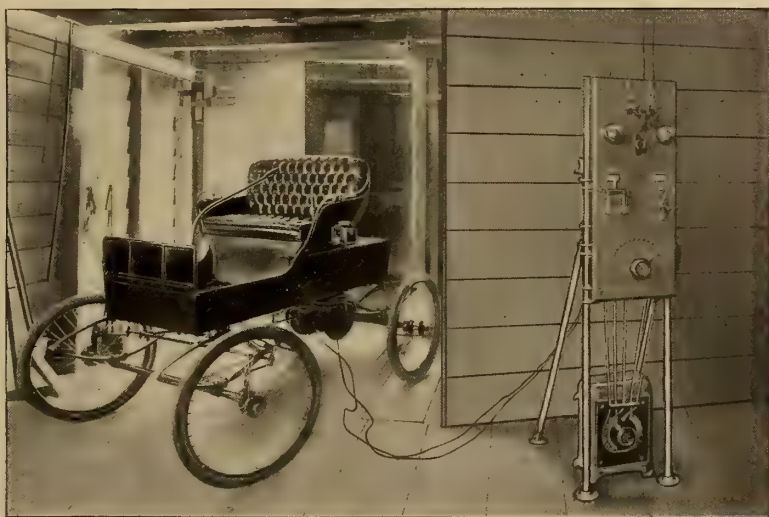


FIG. 10.—WITH THE ELECTRIC VAPOUR CURRENT RECTIFIER, ELECTRIC AUTOMOBILE BATTERIES CAN EASILY BE CHARGED AT HOME

silverware, the grinder for sharpening knives, etc.

Many have probably never heard of the new electric door bell, which in many respects is similar to the ordinary electric door bell as commonly used for years; but this new one eliminates the use of batteries, which from time to time need renewing, and unless the owner or occupant of the house is mechanically inclined the renewal of the batteries generally means something more than trifling expense. The first cost of the new door bell installation represents the only expense at-

duction of the electric rectifier for charging the batteries. Until this rectifier was a commercial success, the batteries of the electric carriage could not be charged at the owner's home, because the supply of current on his circuit was not of the right character. With the introduction of the rectifier, however, the electric automobile can be charged in any home regardless of the character of electricity used. Therefore, when a new home is under consideration, the stable, as well as the house, is wired complete for electric devices.

THE STEAM TURBINE

ITS PRESENT STATUS AND FUTURE DEVELOPMENT

By A. H. Gibson, B. Sc., Wh. Ex. L.

THE steam turbine during the last few years has been brought prominently forward as a rival to the reciprocating type of prime mover, seriously threatening the supremacy of that type until at present it is almost universally admitted that the turbine, in view of the many mechanical advantages common to it and its extremely low steam consumption, is destined to supplant the reciprocating engine for a great many motive purposes.

The purpose of this article, however, is not to compare these two types of prime movers, but to consider the various lines along which the turbine has developed in the past, the advantages and disadvantages appertaining to the types thus far evolved, and the directions in which future developments may be looked for.

All the steam turbines now on the market can be placed into one of two great classes, these classes differing from each other in the manner in which the energy of the steam is converted into useful work on the turbine shaft.

The first of these classes is called the reaction class of turbine from the principles underlying the action of the steam during expansion, and includes the various types of the Parsons, the Rateau, and the Zoelly turbines.

The second class, known as the impulse class of turbine, includes the de Laval and the Curtis types, and finds its most modern development in the Riedler-Stumpf turbine.

The Parsons turbine and its modifications are at the present time by

far the better known and occupy the greater attention of the engineering world. Several reasons account for this fact.

The large sizes of the Parsons turbine have been longer on the market than any other, and the Parsons was the first turbine to compete with the reciprocating engine at a time when the steam turbine was thought by most engineers to be a mere scientific toy. The very excellent results obtained from it in the way of steam economy, together with its proved reliability, its small cost of maintenance, and the small amount of attendance required, have justified the confidence which has been and is being shown by the continued installation of so many and such large units. So far the total capacity of this type of turbine installed in Great Britain and Europe alone amounts to more than 600,000 H. P. The great confidence in this type of machine is shown in a striking manner by the fact that when it was decided to install turbines for the purpose of driving the new 25-knot Cunard liners, the total power required being 70,000 H. P., no other type was even considered.

The next turbine to appear, and to give results enabling it to compete with excellent prospects of success with the reciprocating engine, was the de Laval, patents for which were issued some time later. Since then various modifications of this type have been put on the market, the Curtis and Riedler-Stumpf being the most notable.

The Parsons type of turbine uses steam by passing it through alternate

rows of fixed and moving vanes; the steam gradually falls in pressure in its passage through the turbine, and gives up its energy in steps to the various rings of moving vanes until it finally expands down to condenser pressure, and enters the condenser.

One great advantage claimed for this type is its comparative slow rate of rotation, this enabling it to be used in marine propulsion for the driving of screw propellers. But in order that this slow speed may be efficiently obtained, it is necessary that the velocity of the steam when entering each ring of movable blades, should be comparatively low, and this necessitates that the fall in pressure between any two rows of moving vanes should be small,—not more than 2 or 3 pounds per square inch. In a turbine using steam at 200 pounds pressure and condensing, this means that about eighty rows of fixed vanes and the same number of moving vanes are necessary, obviously necessitating a long and heavy rotor, and expensive construction.

Again, owing to the fact that expansion of steam and consequent transformation from pressure energy to kinetic energy is taking place in each ring of moving and of fixed vanes, it follows that there will be a tendency for the steam to leak around the periphery of the rotor, and between each two rings of moving and of fixed vanes, thereby escaping without doing useful work. This tendency toward leakage is to some extent removed by making the clearance between successive rows of blades and vanes extremely small.

The necessity for so small a clearance affects the turbine adversely in two ways. In the first place, unequal expansion of metal caused by unequal heating of the rotor and its casing, the possibility of which is greatly increased by the great length of the rotor, will cause rubbing to take place between guides and moving vanes, while settling of the shaft, due to excessive wear of the main

bearings, will cause rubbing at the periphery of the rotor.

In the second place, any liquefaction which may take place in the turbine, owing to the steam doing work and losing heat in the process, will cause a film of moisture to be deposited between the casing and moving parts of the rotor; this, in addition to producing a viscous resistance to rotation, increases the rate of leakage of the steam.

The large number of rows of vanes tends to inefficiency in another way. Suppose saturated steam be used. This steam becomes wet in the first row of vanes, owing to its doing work, and becomes wetter as it passes through the turbine. Now, when this steam enters the first row of vanes, and all consecutive rows, it is constrained to follow a curved path, and the particles of moisture held in suspension, being denser than the remainder of the steam current, are deposited by the centrifugal action thus set up, on the outer surfaces of the curved vanes. The frictional resistance between this film of water and the surface on which it is deposited is much greater than that between the steam current and the surface over which it passes, so that the moisture will leave the first set of vanes with a velocity considerably less than that of the accompanying steam. The effect of these comparatively slow-moving particles of water being projected into the swiftly moving current of steam is difficult to estimate. It will certainly tend to set up unsteady motion and produce eddies in the steam current, and so reduce by an unknown amount the velocity of the steam.

From the fact that for efficient working, the angles of the vanes for admission as well as the area of the passages, must be proportioned to suit certain definite velocities of steam at definite points in the turbine, it follows that this factor must tend to reduce the efficiency. Since the steam is continually getting wetter in its passage through the tur-

bine, and since this action occurs at each row of guide blades and vanes, the action will be cumulative, and the larger the number of rings of vanes, the more deleterious does it become.

Although a steam jacket would add to the complexity of the turbine casing, yet this type of turbine is so obviously fitted to take full advantage of the benefits to be derived from jacketing, that the steam jacket will probably be an inseparable adjunct of the Parsons turbine of the future.

Another disadvantage peculiar to this type of turbine arises from its method of governing. From the manner in which it uses steam, it is evident that if unresisted expansion of steam with consequent loss is to be avoided, steam must be admitted around the whole periphery of the first ring of guide vanes, in which case the only way of regulating the speed of the turbine is to reduce the pressure of the steam supply by throttling.

In practice, the double-beat drop admission valve is kept in a state of continual vibration on its seat by depending on the height of the governor shaft, and which works one of the pivots of the governor levers. The amount of its lift is regulated by the governor, so that steam is admitted periodically in gusts at boiler pressure, the duration of each gust depending on the height of the governor. Between these gusts the pressure and temperature of steam in the steam chest fall, and a periodic variation of pressure and temperature which extends through the turbine is set up. This variation of temperature creates conditions similar to those which occur in the cylinder of a reciprocating engine, with the result that initial condensation with all its concomitant evils—increased leakage of steam and increased liquefaction with its attendant evils—is set up. This effect also would be greatly diminished by the use of an efficient steam jacket.

If now we turn to the impulse class of turbine, we find that most of the objections previously noted are overcome. In this class the pressure energy of the supply steam is turned into kinetic energy before the steam is admitted to the turbine proper. This is done by allowing it to flow through diverging nozzles before impinging on the rotor vanes. The steam expands in these nozzles, practically following the adiabatic law,—since the conduction of heat to or from the steam during its passage through the nozzle is very small indeed. The steam falls in pressure and increases in volume and velocity until, if the nozzles are correctly designed, it emerges and impinges on the moving vanes at a pressure which, in the case of a condensing de Laval turbine, is that of the condenser. It still contains its original amount of energy less that used in overcoming frictional and eddy losses, but it is now in the form of kinetic energy. In the Curtis and Riedler-Stumpf turbines this change from pressure energy to kinetic energy takes place in two, three, or even four stages, the steam after each expansion being led through one or more rows of moving vanes where its velocity is abstracted from it and its energy turned into work done on the wheel.

By this method the velocity of efflux of the steam at each stage can be considerably reduced, and the peripheral velocity of the rotor, which when only one row of vanes is used, as in the de Laval, should be approximately one-half that of the steam for maximum efficiency, can also be reduced to a corresponding extent.

In the Curtis and Riedler-Stumpf turbines, too, the velocity of the steam jet is not reduced in one step as in the de Laval, but in two or more stages by passing the steam issuing from the first row of moving vanes, through suitable guides which direct it through a second set of moving vanes in the Curtis turbine,

or again through the same set in the Riedler-Stumpf turbine. Although this compounding and abstracting of velocity in stages cannot be performed without largely increasing the surfaces to the flow of high velocity steam, and hence increasing the skin friction and the liability of unsteady motion in the steam, yet it has a more than compensating advantage in rendering possible the reduction in peripheral velocity of the rotor.

In the Riedler-Stumpf turbine, by the use of nickel-steel of high tensile strength for the rotor and by milling the buckets out of the solid rim, it has been found possible to use a rotor of large diameter,—6 feet 6 inches in the case of a 2000-H. P. machine, and to get a sufficiently high peripheral speed when running at 750 revolutions per minute. The single-wheel Riedler-Stumpf turbine, expanding the steam in one stage and abstracting the kinetic energy in two stages, runs at about 300 revolutions per minute, while the Curtis runs at 1500 revolutions per minute, or at about the same speed as the Parsons turbine.

In the de Laval turbine, however, speeds of from 10,000 to 30,000 revolutions per minute are necessary to get the required peripheral velocity, and this necessitates a reduction of speed by spiral gearing,—a reduction of 10 to 1 being common. It is clear, then, that machines of the impulse class can be made to run as slowly as those of the reaction class.

The fact that only a single disc—or at the most two or three, with only a few rows of vanes—is necessary, enables a machine to be constructed which is light, cheap in construction, and economical in floor space. In the de Laval turbine of 300 H. P., the rotor is only 30 inches in diameter and weighs approximately 500 pounds, while in the Riedler-Stumpf 2000-H. P. turbine the rotor weighs only 1875 pounds. It is thus possible to carry the whole weight of rotor and generator armature on

two bearings, and owing to the small length of the turbine it becomes possible to place the rotor shaft vertically and to fix the generator above the turbine. This is done in the Curtis and in some Riedler-Stumpf machines, and leads to a very compact and convenient unit.

The pressure and temperature of the steam after passing through the nozzles being low, losses due to radiation of heat, and all difficulties caused by expansion of the rotor or casing, vanish. The casing, being obliged to withstand only a small internal or external pressure, can be made of light construction, while the main bearing, not running the risk of being overheated by conduction from a hot casing, can be brought very near to the rotor. Advantage can also be taken of any degree of superheat, since the steam which enters the turbine proper, having already expanded and done work in the nozzles, has become saturated and has fallen in temperature to that corresponding to its pressure regardless of the original temperature of superheat.

Again, since a steam jet of very high velocity shows very slight tendency to lateral dispersion for short distances after leaving the nozzle, this allows a comparatively large amount of clearance between the nozzles and the moving vanes. It also obviates all possibility of rubbing, due to any possible wear at the bearings, or unequal expansion, and insures that the efficiency of the turbine shall not diminish with continuous running. In the impulse class of turbine, governing is always performed by cutting off steam entirely from one or more supply nozzles, the remaining nozzles being unaffected, so that whatever steam enters the nozzles does so at full boiler pressure. It follows, therefore, that the velocity of efflux of the steam from the nozzles is constant at all loads, so that, except for the effect of friction which is greatest at light loads, the efficiency of the machine

will be the same for light loads as for heavy loads.

The pressure and the temperature at any point in this type of turbine is also the same at all loads, so that there are none of the fluctuations of temperature, and initial condensation caused when the governing is done by throttling the steam. By supplying more nozzles than are required for driving the normal load, considerable overload can be carried by the turbine, and on account of the proportionately smaller effect of friction at high loads, the efficiency will increase with the overload.

A further advantage possessed by this class of turbine, and which is very commonly overlooked, is its ability to start under full load. This is a property not possessed by the reaction class, although in a turbine used for driving an electric generator or for marine propulsion, this feature is unnecessary, since the load comes on gradually as the speed increases; yet in a turbine intended for the direct driving of a cotton mill or other factory, it is of the greatest importance. This property arises from the fact that whereas with an impulse turbine the turning moment on the shaft is greatest when the steam jets impinge on a fixed wheel, with a turbine of the reaction class the effect of fixing the rotor is to reduce the turning moment, the steam simply escaping through the blade openings into the condenser without doing any useful work.

The small number of rows of vanes has also another advantage. It has been shown how particles of moisture in the steam passages affect the motion of the main current of the steam, and how this effect is cumulative, becoming worse as the number of rows of vanes increases. When, as in the de Laval, only one row of vanes is used, the presence of moisture is, from this point of view, quite innocuous.

A further property of the impulse turbine, which, except when being applied to marine propulsion, is also

an advantage is, that the steam in each chamber, being at the same pressure throughout, each disc is practically in balance as regards axial thrust; thus the need for the balance pistons, which are necessary in all single-flow turbines of the reaction class, is removed. This property is, of course, a disadvantage when the turbine is intended for marine propulsion, as there the end thrust on the rotor shaft may be utilized to balance to some extent the thrust of the screw propeller, considerably reducing the thrust to be transmitted by the thrust block.

This end thrust has been obviated in the Westinghouse-Parsons turbine by arranging two turbines tandemwise on the same shaft, the steam flowing axially in opposite directions in the two turbines, and thus neutralizing the effect.

When we consider the results as regards steam consumption which have been obtained up to date by the various types of turbine, it would appear that the reaction class is slightly the more economical. It must be remembered, however, that considerably more time and money have been spent in bringing this class to its present state of perfection than in the case of the more recently developed impulse class, and that for very large powers where the impulse class, as represented more particularly by the Curtis and Riedler-Stumpf turbines, might be expected to give good results, the reaction class has so far almost had a monopoly.

The table on the next page shows what are, so far as the author is aware, the best published results of trials of each type up to date.

In view of the then very many and very real advantages common to the impulse class of turbine, it would appear that future development is to be looked for along these lines, and that the reaction class of machine is labouring under disadvantages natural to its method of using steam, which will in the future handicap it very

STEAM TURBINE DATA

41

THE LATEST TRIAL FIGURES FOR STEAM TURBINES OF DIFFERENT MAKES

TYPE.	Power.	Load.	Steam Pressure Lbs. per Sq. In.	Superheat Degrees Fahr.	Vacuum Ins. of Mercury.	Speed Rev. per Min.	Steam Consumption Lbs. per EHP. per Hr.
de Laval.....	300 BHP.	357 BHP.	208.	81	27.2	750	13.55
de Laval.....	300 BHP.	342 BHP.	151.	20	0.	755	15.4
Parsons.....	3,000 KW.	2,993 KW.	138.5	235	27.0	1,350	11.0
Parsons.....	1,000 KW.	1,173 KW.	130.	92	28.4	1,493	13.6
Westinghouse Parsons.....	2,500 KW.	3,669 BHP.	150.	0	26	1,480	12.6*
Westinghouse Parsons.....	1,500 KW.	1,500 KW.	150.	140	28.0	...	12.4*
Westinghouse Parsons.....	1,000 KW.	1,346 BHP.	150.	152	27.47	1,808	11.43*
Westinghouse Parsons.....	500 KW.	763 BHP.	150.2	182	28.08	3,478	11.17*
Riedler Stumpf.....	1,500 KW.	1,430 KW.	128.	307	27.7	3,800	12.97
Curtis.....	2,000 KW.	2,000 KW.	180.	200	28	900	11.41
Curtis.....	2,000 KW.	2,000 KW.	180.	125	28	900	12.08

*In these four cases the steam consumption is figured per B. H. P.

considerably in the race for supremacy. The chief drawback at present to the impulse class arises from the fact that a current of high-velocity steam requires very delicate handling if its flow is not to become unsteady and if eddy motion is to be avoided. This involves extreme care in devising the nozzles and in designing the shape and varying areas of the steam passages; it is, therefore, in the improvement of these details that future development may be looked for.

If the gas turbine becomes a commercial success, it will undoubtedly be by development along these lines. The moving fluid in this case, because of its comparatively high specific gravity, lends itself more readily than does steam to the impulse class of turbine.

Again, owing to the very high temperature of the formation of the working fluid, the impulse method reduces the temperature of the fluid before its admission to the turbine proper, by expansion in the diverg-

ing nozzles, and is thus the only practicable and convenient means of overcoming the difficulties caused by such high temperatures.

Since the gas on entering the turbine casing will be at a comparatively low temperature, the necessity for a water jacket, which generally carries away about 40 per cent. of the total heat generated in a gas-engine cylinder, is obviated, and a direct saving over the gas engine of this amount of heat is obtained in addition to the advantages of this type of prime mover from a purely mechanical point of view.

It would appear then that we are at present well in view of the ideal prime mover, economical in working and in first cost, simple in construction and of unimpaired efficiency after long periods of operation. When we add to this its adaptability for most of the purposes for which a prime mover is required, the gas turbine would appear to be an ideal worthy of the aims and aspirations of every mechanical engineer.



FOUNDATIONS FOR PUMPING ENGINES

By Charles A. Hague



IN the consideration of foundations for the support and anchorage of pumping machinery, especially for the larger sizes, it is very difficult to establish any fixed or exact rules. Many attempts have been made and much time has been lost in endeavouring to establish some sort of formula for reaching satisfactory results; but there are so many

changing circumstances, variations in conditions and incidental considerations that it is difficult to see how the question can have a theoretical side at all.

The only principle of material value is the one which involves the loading of the foundations expressed in pounds pressure per square foot upon the bed, so as to be within a safe working limit. And in the matter of load upon the foundation bed, it is extremely necessary to make the important distinction between a live load, such as a working engine, and a dead load, such as the walls of a building. It goes without saying that a heavy, strong, and suitable foundation is absolutely necessary for the best results; and this is especially so in the case of pumping engines and other forms of steam-driven motors. There are, of course, all sorts of rules and ideas concerning the speed of machinery, weight,

length, breadth, and depth of foundations, but the situation and conditions, as in all other matters pertaining to the accomplishment of any definite purpose, must largely govern the efforts in these directions.

A pumping engine comes under the head of "live loads" upon a foundation as opposed to anything which does not of itself embody a living and moving force; and a good general rule, with reference to the pressure per square foot upon the bottom or upon the bed of the foundation, including the weight of the foundation itself, is that when upon ground or soil there should be an allowance of 800 pounds load per square foot of area. This will give enough area to the bottom for any good, firm soil. With rock for a bed, a less area of bottom will be sufficient; and, in fact, the least area consistent with sufficient space to support the machinery at the top of the foundation will answer the purpose with a rock bed. It is only when the work must rest upon a bed of soil, clay, gravel, or other earthy material, in the absence of rock bottom, or in case of such extreme depth down to the rock, that the excavation and subsequent filling with foundation material is very costly and troublesome, that the bearing pressure is to be brought down to what may appear to some as the low figure of 800 pounds per square foot of bed.

Foundations may sometimes be unnecessarily expensive on account of cut stone caps, cut anchor plate stones, and other costly trimmings; but it cannot be too solid. The idea of a foundation for a working living engine is to make it as nearly as

practicable represent a fixed part of the entire mass of the earth by its weight, spread, and bearing; and when this is accomplished to the extent of preventing all settlement, tremor, or disarrangement of any kind, the stability and operation of the machinery will be assured, so far as its installation and location is concerned.

The foundations for the smaller sizes and capacities of pumping machinery are generally ample, apparently because the cost is not very great any way, or it is comparatively small, and simple in form. But as the magnitude of the plant increases, the proportion of the smaller unit carried out in the larger unit seems to make the dimensions and cost loom up to an extent which startles the designer. Of course, the fact is partly, perhaps principally, that with small machinery, say, a 2,000,000-gallon horizontal pumping engine, just a monolith or solid mass of masonry of the required length and breadth, and perhaps three, or, at the most, four feet deep, is easy and inexpensive to build; but when it comes to a vertical pumping engine of the highest type and of considerable size, for example, of 15,000,000 gallons capacity, the foundation is calculated very closely,—many times too closely, to the sorrow of the buyer at some later day.

It can be stated with the certainty and authority of a self-evident proposition that money invested in a proper foundation is money well invested, and that money kept out of a foundation to the extent of jeopardizing the success of the machinery expresses a saving very badly misplaced. In fact, if the question must be settled between apparent extravagance and misplaced economy, then the extravagant side of the case ought to be favoured in the interest of safety, low repairs, and economy of operation. Each case ought to be considered and decided by itself, as experience shows that no general rule can be followed, on account of

the great variety of underground and underwater conditions, unknown and unseen until actually dug down to and exposed. Foundation making is not quite so purely an art as stone quarrying, but there is not so very much difference between them as at first might appear.

When a new pumping engine is to be put into a building already in existence, very great care is necessary to avoid doing damage to the building, its foundations and walls. Frequently it is necessary to underpin the building walls before the engine foundation can be commenced. The writer in his own experience lately had such a task in hand, and the first thing done was to excavate a pit about 5 feet in length in line with and close to the wall; this pit was carried down to the bottom of the building foundation, and this was found to be resting upon sand and gravel. It being necessary to go still deeper to accommodate the new engine, which was a vertical triple-expansion machine of 15,000,000 U. S. gallons capacity, this pit, 5 feet along the wall, was continued down some 12 feet below the bottom of the building foundation to rock and large boulders. Such a limited excavation had no effect whatever upon the wall. The pit was then carried underneath the wall the entire thickness of the building foundation, and when rock was reached or large boulders sufficiently firm to indicate that no disturbance would take place, a bed of concrete was laid some 3 feet in depth, and upon this concrete base a pier of brick, laid in strong cement mortar, was carried up to the bottom of the building foundation at that point, thus completely underpinning and solidly supporting the building wall.

After this first pier had set sufficiently to ensure a proper resistance to compression, another pier was put down to the rock in a similar manner and about 5 feet away from the first one, and this process was continued until about 25 feet of the

walls at both sides of the building were completely supported upon these intermittent piers. Then the spaces between the piers were excavated down to the rock, and so this new and what might be called a sub-foundation was made solid and continuous. Next, the ground within the building was protected by cross retaining walls, and then the entire space extending clear across the building, and some 20 feet lengthwise of the building, was excavated down to the rock and large, heavy, immovable boulders, upon which a bed of concrete made a substantial, highly satisfactory bed for the foundations for the new pumping engine. The walls of this pumping station above the main floor had been lined with a high quality of white enameled brick with very precisely pointed joints; and after the foundation work had been completed, including the foundation for the pumping engine, there was not the slightest trace of any crack or settlement in the finished surface of the walls.

In making contracts for pumping engines it is often, nearly universally, the practice to include the foundations within the contract for the pumping machinery. But to the author's mind this is more often a mistake than otherwise, for, to stipulate that the builder of pumping engines must provide all sub-foundations, foundation proper, do excavating, cut into and replace masonry, floors, walls, and whatever may be changed in the course of the installation of the machinery, is to inflict upon the maker of such machinery a lot of work entirely and completely outside of his legitimate business and occupation.

The belief, supported by experience, is that the best course for the buyer of pumping machinery to pursue with reference to his own interest is to exempt the engine builder from all work and responsibility outside of the machinery itself, leaving to him only that which he is prepared to handle, and thus leave his

mind free from the haunting shadow of matters foreign to his business, which he cannot meet without an element of uncertainty as to cost, and the reflection of which most surely comes back to the buyer in the shape of increased price by reason of percentages added by the machinery maker to cover possible contingencies of which he cannot accurately inform himself beforehand. The case just referred to, concerning the underpinning of the walls of the building, illustrates this matter very clearly.

Still another and fully as good an illustration of the bad policy of loading down the mind of a pumping engine builder with affairs which do not belong to him and for which he should not be held responsible, is a case rather more difficult than the one already cited, and also within the experience of the author. A large and important pumping engine, happening to be also of 15,000,000 gallons daily capacity, but against a considerably greater head than the last one cited, had been contracted for. This engine also was to be located inside of a building already in existence and so situated that it could not have been replaced upon the premises; therefore, it meant a goodly sum of money saved to the buyer to utilize the present building, only a moderate amount of alterations being necessary in the building itself. The foundations of this building were not any too stable in construction, and rested upon rather a hard limestone bed rock about 12 feet below the main or engine room floor. From the corner of the building the rock extended at the depth of 12 feet about level, in line with one of the walls, and ascended about 4 inches to the foot along the line of the other wall, these two walls being the walls forming the 90-degree angle making the corner of the building.

The plans for the new engine indicated that a distance of 16 feet would be required from the level of the engine room floor to the under side of

the sole plates beneath the water end of the machine, and in addition to this it would be necessary to allow at least one foot for concrete in leveling up and making the sub-foundation. This meant that the new work would extend down into the rock 5 feet below the building foundation at one side of the engine and 13 feet below the surface of the rock near the middle of the building at the other side of the engine. The problem, of course, was to excavate nearly straight down into the rock until a foundation bed was formed, practically although roughly level, and 17 feet below the engine room floor, leaving the foundation of the building along the two walls forming the angle, standing within about a foot of this new excavation in the rock.

The building foundations not being of any too compact a character, it was decided to underpin the building with concrete piers extending through the original foundation walls and placed directly beneath the wall piers between the windows, the corner or angle being taken care of in a very thorough and complete manner by means of an extra heavy concrete angle pier.

After the walls had been thoroughly protected, the earth was excavated down to the rock, and retaining walls of concrete were formed to hold back the earth in the other parts of the building where no basement existed, and then the earth covering the space where the new engine was located, and having dimensions of 42 feet by 24 feet, was excavated and removed from the building, leaving the rock exposed where the new machinery was to be placed. Then, commencing near the middle of this area of exposed rock, a pit was formed down into the rock by very light blasting, barring, and picking, the pit being gradually increased in size and deepened until the required depth was reached, forming a space at the bottom about 10 feet square.

These operations of blasting, barring, and picking were continued around the sides of the pit until the rock excavation was finally completed of the desired size, shape, and depth. A bed of concrete was then rammed into place until a clean, true and level surface was formed just the required distance below the engine room floor for the accommodation of the water end of the new pumping engine. The holes for the anchor bolts were then laid out and drilled by diamond core-drills to an average depth of about 5 feet, the bolts being secured in the rock by well-known wedging devices.

Where an entirely new pumping station is built and arranged for pumping units, of uniform size so far at least as floor space is concerned, although the future units may be of greater capacity than the first ones, it is very easy to provide for proper building foundations, engine foundations, pump wells, intakes, screen chambers, etc. But to save unnecessary expense in the future these arrangements of building and engine foundations, together with the lay-out of suction and delivery pipes, must be carefully thought out and planned from the start, even though all of the work is not immediately gone into.

There are very few tasks more expensive, annoying, and risky, in proportion to their use, than the cutting, carving, and digging necessary for the placing of new pumping engine foundations within a building already crowded with machinery, pipes, and masonry. At times this has to be done, and largely, no doubt, because the addition, improvements, and enlargements are mostly made in established plants possessing limited available space. The matter of economically providing for the future is not so difficult as it may at first seem; and the unit system may be so arranged that a plant, whether large or small in pumping capacity, could be composed of what might be called compound units, or plant units. Hav-

ing compound units means to place the machinery in groups, as, for example, four, five, or six pumping engines or pumping units in one complete building, the building forming a plant unit. Then, when in the future it became apparent that more capacity was needed, instead of attempting to build onto, or enlarge an existing building, make the plans for another group or plant unit, conforming, of course, to any changes or improvements which might have been developed since the last plant unit was built.

In this way, having some definite line to work to, the matter of future foundations and other accommodations for the machinery could be intelligently provided for, although no more of the actual work need be done than the present demands call for, the main thing being to look ahead and establish the possibilities for future improvements which, when the time came, could be placed without annoyance, undue expense, or interruptions of the waterworks service. It will surprise many to observe, after a little study, how much satisfactory work and planning can be done in this direction.

A great deal could be written upon the subject of pumping engine foundations, but in the absence of opportunities for laying down hard and fast rules which would be of practical use for future work, such writings would naturally have to be confined to work already accomplished, and beyond the study of materials and methods of construction in particular cases, not much real good could be accomplished. A student, an engineer, or a waterworks manager would have to determine in the special cases met by them how far the record or history of work already accomplished could be properly applied to new cases in hand.

Where excavation, building new foundations, retaining walls, underpinning or similar work is to be done, it will be necessary to ascer-

tain by local conditions and evidence what the character of the soil or earth may be for quite a considerable depth about the locality. In soil, no matter how durable it may appear, even after excavations have been made, it will be well to ascertain by drift rods, drills, or augers, or other means of sinking test holes, to what depth a suitable and firm foundation bed may be depended upon. Whenever a considerable depth has to be tested, it is very often a good plan to drive down a piece of wrought iron pipe, and, if necessary, this pipe can be made up of moderate lengths successively screwed together by the ordinary pipe couplings so as to increase the convenience of driving. It is not difficult or uncommon in ordinary soils to cheaply go to the depth of 40, 50, or even 100 feet for testing purposes by the use of the above-mentioned or similar appliances.

Rock, of course, is always to be preferred for the bed of pumping engine foundations, but as it cannot always be reached within a reasonable distance, it is extremely important to determine what course can be safely followed under other and less desirable circumstances. For example, where reasonably tough or strong soil overlies rock to a depth of 12 or 15 feet below what would be suitable for the building foundations, but where it would be preferable to have, if possible, the support of the rock for the engine foundation, it is quite practicable to excavate small circular or square pits through the soil and down to the rock, these pits being dug one at a time, and filled with concrete from the rock up to the level of the building foundation, and enough of them put in proper position for taking the support of the engine foundation and thereby transmitting the weight and pressure of the machinery and its foundation directly to the rock without interfering with the stability of the building walls. It is quite practicable to follow this prac-

tice even where the soil is not so very firm, by first sinking tubes or caissons made of steel or iron plates, carried down to the rock and afterwards filled with concrete. The result of this method, either with or without the caissons, is to support the engine foundation upon concrete piles or columns, reinforced by earth.

Such a case is recalled to mind where the pumping station was located about 300 feet from the river edge and had been built for the accommodation of two horizontal engines with space left for two more, the engine room being oblong and the engines placed crosswise. The foundations of the machinery had been built upon the same soil as the building walls, a mixture of sand and gravel. The weight of the horizontal engines, quite moderate in proportion to capacity, was rather evenly distributed, and incidentally had the advantage of great area of foundation bottom in proportion to the weight of the machinery, the load upon the foundation bed not exceeding 400 pounds to the square foot. This light load had probably not been sought for, but was purely incidental to the shape, dimensions, weight, and disposition of the machinery. These two engines had been in service so long that the gross demands for water had increased until it very nearly equaled their combined capacity.

After it had been decided to increase the capacity of the station, an investigation of all the circumstances resulted in a recommendation to utilize the remaining space in the building by putting in a vertical triple-expansion crank and fly-wheel engine, equaling the combined capacity of the two original machines. Fortunately, for architectural effect, the building had been made rather lofty for the accommodation of horizontal machinery, so that by going down to a considerable depth for foundations, the proposed new vertical engine would just about fit the case.

The floor in the reserve portion of the building was removed and excavation commenced. There was a basement to the building, and the foundations of the walls extended a few feet below the basement floor. It was found, by sounding and boring, that there was bed rock about 20 feet below the basement floor and practically level beneath the location of the proposed new engine, and it was also found that the upper surface of the lower flat portion of the engine foundation would have to be at the level of the bottom of the building foundations.

It was soon ascertained that the underpinning of the building walls would be rather expensive, and it was, therefore, decided that 4 feet would be thickness enough for the bottom portion of the engine foundation, and under the circumstances 4 feet were considered to be the safe limit of depth to go into the soil below the level of the building foundation. This would leave about 11 or 12 feet of soil, more or less uncertain in quality and exposure to saturation, between the bottom of the engine foundation and the rock.

After looking the matter carefully over, the conclusion was reached that the best plan would be to sink a number of wells, about 4 feet square, down to the rock and so provide solid supports between the rock and the bottom of the engine foundation. This was successfully carried out, although in some of the holes it was necessary to place sheathing of planks and cross bracing to safely support the soil while the concrete pillars or piling were being rammed into place. In all cases where the sheathing was used, the bracing was taken out as the level of the concrete was brought up, but in some of the holes it was found necessary to leave the planking in place. The 4 feet of depth between the top of the concrete piling and the bottom of the building foundations were carefully protected at the sides by planking and bracing until the bed of con-

crete was safely rammed into place. The planking around these sides, having been placed vertically, was easily removed, and the soil was thoroughly compacted against the sides of the concrete.

Upon this platen or cake of concrete, 36 feet long, 20 feet broad, and 4 feet thick, forming practically a large flat artificial stone, solidly supported from the rock and with its upper surface at the level of the bottom of the building foundations, the pier for supporting one end of the engine bed plates at the floor level was built. The new engine, of 12,000,000 U. S. gallons capacity, against 200 feet head, was erected in place and put into service without any evidence of cracking or settlement of the masonry appearing after a lapse of nearly a year, and it is to be presumed that the future will show equally as well.

Sometimes situations are met where a yielding soil is found to overlies firm gravel, hard, compact sand, hard pan or rock, with the upper material too deep to permit of excavation down to the firm material or to carry down concrete columns, as already referred to. In such cases piling may be resorted to with success, provided the harder material can be reached by the lower ends of the piles, and through such support, aided by the compacted earth, a satisfactory foundation bed may be secured.

But where the soft material is so deep that a hard bottom cannot be reached by the piling, nothing but the most urgent necessity should permit the location of pumping machinery in such a place. Of course, the compacting of the soft earth between the piling will take place and a comparatively homogeneous mass will result, but even though the individual piles will be little liable to sink, the entire mass, as a whole, will be likely to settle in the course of time. This may not be particularly injurious to a building or a dead load, but entails a good many risks to a

live, moving load, like a pumping or a power engine,—risks which had better not be taken. I am well aware that such things are occasionally done, but do not believe in them, and strongly advise against them.

If piling must be resorted to, the situation of the machinery in a particular spot making such location very important, and the use of piling a secondary matter, especially if a hard bottom can be reached by the lower ends of the piles, these should be placed ordinarily with about two and one-quarter times the diameter of the pile between centres. The tops should be sawed off to a uniform level, and, if necessary, capped with a grillwork of timber, some arrangement of heavy planking or other device deemed best for the situation, although too much timber work should be avoided on account of the changes which more or less dryness or dampness of wood may occasion, it being remembered that these changes come laterally, but, as a rule, not at all lengthwise of the timber. Then a bed of concrete, from 3 to 6 feet in thickness, covering the entire surface of the tops of the piling and the timber, will provide a substantial bed upon which to build the engine foundation. Sometimes, where the conditions admit, concrete is placed over and around the heads of the piling without the intervention of grillwork or planking, and, where possible, this method is to be preferred, on account of the absence of chances for cross shrinkage of the timbering.

Of course, the walls of the building should be firmly supported upon piles, if necessary, but independently of the foundation bed for the machinery. No special rules or directions can be safely given for such work, for the simple reason that when the situation demands such treatment of a foundation, this is evidence enough that each case should be considered by itself. The conditions are too variable and uncertain for hasty conclusions in the absence

of a full knowledge of all the facts. The safe load upon piles of 12 inches diameter at the top, when driven in firm soil and without the bottom end resting upon hard-pan or rock, should not be reckoned at more than 15 to 18 tons per pile, with a dead or still load, and at not more than 8 tons with a live load, like a steam engine at work.

A good specimen of a large pumping engine foundation supported upon piling is the following:—

The material just under the top soil and immediately at the surface was a fairly firm yellow clay, while about 65 feet beneath the drill indicated an unusually close-knit gravelly hard-pan. The pumping engine was a very heavy vertical, cross-compound, condensing machine, of the differential plunger type, and, with its foundations, needed a space of approximately 70 feet in length and 30 feet in breadth. After carefully sounding the material at the location of the proposed station, it was decided to put down piling through the clay to the hard-pan for the engine foundation, and then place the building foundations on the clay at a sufficient depth to guard against frost and moving surface water, the material, when well rammed and in a state of rest, being impervious to water.

At the site of the engine foundation the top soil and clay were excavated 29 feet below the surface of the ground, and piles, 16 inches in diameter, were driven to the hard-pan. It was perfectly evident when the hardpan was reached by the bottom end of the pile. The tops were sawed off to marks set by an engineer's leveling instrument, and timbers, 16 inches square, were spiked in place crosswise of the work and on top of the piles, sufficiently to keep them from moving so that concrete could be rammed around the heads of the piling and the cross timbers, the concrete being carried up until it was 3 feet above the top surface of the cross timbers. The

piles were set 36 inches from centre to centre, lengthwise and crosswise, and as the main pumps were of the wet-well variety, the piling and timbers would always be wet enough to prevent changes.

Upon this bed of concrete were placed dimension stones, 36 inches thick, and as large as could be procured and conveniently handled, these stones forming the bed for the vertical water cylinders, and the seats for the massive brick piers and wing walls which supported the upper portions of the engine, and also formed the wet-well from which the water was pumped. An arched conduit, built in the brickwork, and provided with a suitable gate, formed the inlet passage for the water into the well.

Authorities vary as to the safe load that may be placed upon earth foundation beds, and give all the way from one ton to four tons per square foot, but mostly still loads are referred to. So far as the author is concerned, however, where permanent and lasting results are looked for with smooth and economical working pumping engines, the limit is put at 1000 pounds per square foot, and preferably 800 pounds for the machinery and 3000 pounds for the building walls of the pumping station, when the bed is even the best of earth. An equally distributed pressure is to be carefully sought after, and in the absence of a rock bed or its equivalent, it is well worth the while to pay particular attention to the uniform distribution of pressure.

As to the matter of material for engine foundations, after the question of bed has been properly decided, a concrete bottom, then the foundation piers of hard-burned, sound brick, with granite, limestone, or hard sandstone anchor bolt stones and cap stones will give as good results as anything, and better than most other materials or combinations of materials. There is a great advantage in brickwork, because brick can be laid up closely and true to the required form, with

full mortar beds and joints. The material will knit together, and, altogether, make a very manageable and practical construction; and when good, hard brick is laid in Portland cement mortar of proper richness,—not too rich, say one of cement and two of sand,—there is nothing more to be desired in the way of solidity.

It is not absolutely necessary to use cap stones, although a better piece of work can be done when cap stones are used; but there should be something in the line of washer stones where pockets for the bottom ends of anchor bolts are arranged to be gotten at when desired. But a brick foundation could be built and finished off smooth enough on top for the setting of machinery, if the cap stones are considered as adding too much to the cost of the work.

In this case the heavy castings would be leveled up correctly, and then cement and sand grout run under them. A thin mortar of three parts cement and one part sand will make a very satisfactory grout, and it should be made pretty rich with cement to make certain of its running properly under the casting. There should be a liberal space, say 2 inches, between the casting and the brickwork, so as to make a solid bed of grout and avoid all chances of the space not filling, as would likely be the case if a thin sheet of grout should be attempted.

If the grout is not pretty rich, say three cement and one sand, it will not flow well, because the cement will take up and follow the water, while if there is too much sand in the grout it will settle before the mixture reaches well under the large castings. Probably 4 feet are about the limit to which grout can be properly run from any one point; so where it is known beforehand where grout is to be used, provisions should be made for pouring from several points about the casting.

The matter of concrete is a very important one, and a strong, compact mixture should be made for en-

gine foundations, whether the entire foundation is made of concrete, as is sometimes done, or whether the lower part or bed only is formed of that material. The best working mixture for concrete for foundations, or for work about water, such as core walls and similar work pertaining to dams, reservoirs, gate houses, etc., is, in the author's opinion, one part Portland cement, two parts sand, and four parts crushed stone. Such a mixture will fill the voids completely and make a close-grained, solid, artificial stone, as will be seen from the following:—

If a wooden box is made, one cubic yard measurement, or 36 inches long, broad, and deep, its cubical contents would be $36 \times 36 \times 36$, equal to 46,656 cubic inches. And, if a perfect globe of stone with a diameter of 36 inches is placed in such a box, of course, it would touch the top, bottom, and the four sides. The cubical contents of the globe would be the cube of the diameter multiplied by the decimal 0.5236, or it would be $36 \times 36 \times 36 \times 0.5236$, equal to 24,429 cubic inches. The empty space, then, will be the difference between these two quantities, or nearly 48 per cent., or, say, practically one-half solid and one-half space or void.

If globes 3 inches in diameter were placed in the box, there would be twelve globes each way for twelve layers, or $12 \times 12 \times 12$, equal to 1728 of the 3-inch globes. The cubical contents of one of the 3-inch globes would be $3 \times 3 \times 3 \times 0.5236$, or 14.1372 cubic inches, which, multiplied by the number of 3-inch globes, 1728, will give 24,429, or the same as with the single globe of 36 inches diameter. This, of course, means that whatever the size of the globes, the result will be that there will be practically half solid and half space or voids.

Crushed stone is not as regular, of course, as the globes just referred to, but the irregularities amount to about the same thing, fitting in to

gether in some places and holding apart in others, so that, take it altogether, the rule of half solids and half voids will hold good. Therefore, when the cubic yard box is filled with crushed stone, there will be room for half a cubic yard of sand in the spaces between the stones; and, again, after the sand is in place, there will be room for half as much cement in the spaces between the sand grains, or a quarter of a cubic yard of cement. As eight ordinary cement barrels full of crushed stone will make a cubic yard, there will be 4 barrels of sand and 2 barrels of cement in the mixture, or 2 cement, 4 sand, and 8 stone; or, as first given, 1—2—4 for the best and strongest mixture for concrete. This cannot be carried out as exactly as the globe figure, but the barrel measurement given above will answer all practical purposes.

To show how closely the sand will follow the same law as the crushed stone, we may assume, for the purpose of calculation, that the sand grains are globes one-fiftieth, 0.02 of an inch in diameter; then $0.02 \times 0.02 \times 0.02 \times 0.5236$ will equal 0.0000041888 of a cubic inch as the cubical contents of the grain of sand. At one-fiftieth of an inch diameter, there will be 1800 grains each way in the 36-inch box, which will make $1800 \times 1800 \times 1800$, or 5,832,000,000, which, multiplied by the cubical contents of each grain, will give 24,429 cubic inches, as before, as the solid contents of a cubic yard of sand, leaving about half a cubic yard as voids if the box contained only sand.

Engine foundations are sometimes built of stone, but unless of cut or at least of dressed stone with true beds and joints, this material is nothing like so good as brick. Rub-

ble stone for such work is very objectionable, unless a good deal of dressing of the stone is done, and this would not pay in the absence of very cheap material. Rough, thick beds and joints in a foundation for supporting a live load are not to be commended at all; they are likely to lead to trouble with the machinery. Rubble work, when put up with reference to core walls, and like work where it can be made watertight, but practically supports no load to speak of, is very acceptable; but for pumping engine foundations it should be avoided.

Concrete foundations are coming more and more into use, and some very well-appearing work has been done in this line, although for heavy, general work, if the truth were known, when proper materials and mixtures are employed, the cost of forms is considered, etc., the price per cubic yard will go above brickwork trimmed with stone, and would be a useless expense. Concrete is excellent for sub-foundations where no special or exact form is needed, and when it can be rammed into place and brought up to some general level, to build the regular foundation upon; but it is not desirable for the upper work in important plants unless special reasons exist for its use.

Large, vertical, self-contained pumping engines, resting upon a bottom sole-plate, extending beneath the entire machine, need nothing more than a flat layer of concrete underneath, although the concrete should be bedded on rock or have some equivalent support; and in such a situation there is probably nothing better than concrete, and considering the difficulties often met with in the lower part of such work, possibly it is the least costly construction that can be employed.

A NOVEL FORM OF GAS HEATING STOVE

By William Paul Gerhard, Consulting Engineer

A SUCCESSFUL and novel form of gas heating stove was recently introduced in Germany. The inventor and manufacturer of this is Professor Junkers, of Dessau, Germany. Figs. 1 to 6 give a very good idea of the appearance of the stove. It is patented not only in Germany, but in nearly all other countries, and a brief description of it may be of interest here.

"Should a heating stove necessarily stand on legs?" asks Professor Junkers in one of his interesting pamphlets describing the new device. He draws attention to the fact that it is difficult to conceive objects, which one has been accustomed from childhood to see in a certain form, being made in a different form. Whoever thought until now of constructing a gas heating stove of a different form and to place it in a position other than on the floor? True, as long as one was obliged to use heavy and compact fuel for heating, one could not very well dispense with the usual, strong legs in the construction of the customary forms of heating stoves. Since, however, wood and coal are being more and more replaced by gaseous fuel, it does seem unreasonable to hold fast to old traditions and to the clumsy forms of our heating stoves.

The new gas heating stoves designed by Professor Junkers are of such peculiar form and construction that they may be attached to the gas supply pipe along the wall at any height instead of being placed on the floor.

Fig. 1 shows a vertical section through such a wall stove. The course of the cold air, of the heated air, and of the hot gases is shown by

three different kinds of arrows. The stoves are constructed of excellent material and the workmanship is of the best. The cold air is drawn in at the bottom, or very near the floor line, and passes upward at the rear behind the reflector and thence through a number of flat tubes, ascending towards the front of the stove, and after being heated by these tubes, which are surrounded by the hot gases from the burner, the air, now warm, passes out into the room vertically upwards, and also forward

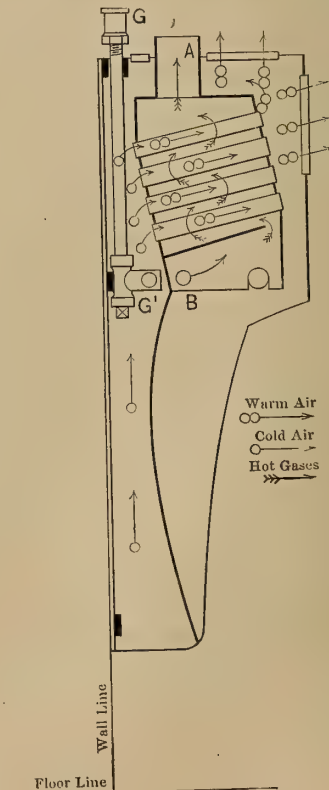


FIG. 1.—VERTICAL SECTION OF A JUNKERS GAS STOVE

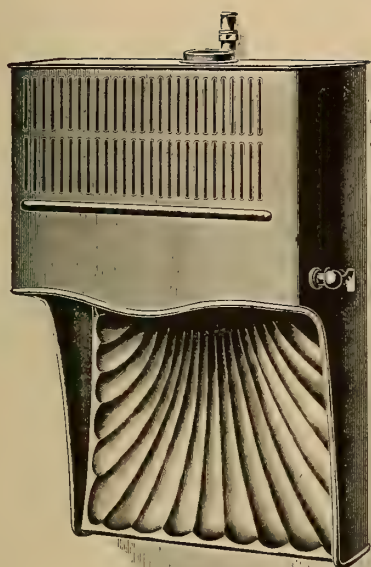


FIG. 2

at the front of the stove. This secures a strong circulation of the air of the apartment, while at the same time the rays from the reflector, which are projected downwards, tend to warm the floor and the lower strata of air. In this way a room may be quickly and uniformly heated. There is complete combustion of the gas, the heat units generated are utilized to best advantage in the heating surfaces, and a very intense heat is produced. The hot gases, after having done their work around the air tubes, pass out at the top through the flue *A*, which is connected with any available chimney flue. These gas heating stoves are odourless and perfectly sanitary, because there is no chance for products of combustion to escape into the room. It should be noted that the wall, or the wall paper, at the back of the stove do not become warm, because it is the cold air which ascends at the back of the stove.

Figs. 2, 3, and 4 show how these novel forms of wall stoves look. They are quickly and easily installed by connecting the gas coupling *G*

at the top of the stove with a gas pipe dropped from the ceiling along the wall. The stove may be placed at any height above the floor, though it is usual to put it at from 12 inches to 20 inches from the floor. No other wall clamps or fasteners are required. Should the gas service happen to be in the floor, a pipe may be easily run up along the wall to the required height, and in that case the outlet *G* is capped and outlet *G'* is connected with the ascending gas pipe. The flue *A* should be connected in the shortest possible way with a chimney flue.

Gas heating stoves attached to the wall have a number of advantages over the usual forms of gas stoves. In the first place, the installation is simple, and easily and cheaply made. In connecting the old forms of gas heating stoves, it was necessary to cut the gas pipe to exact measure, because the heating stove had to stand on the floor. In passing, it may be remarked that a permanent connection by means of wrought-iron piping is much preferable to a temporary gas hose connection, which

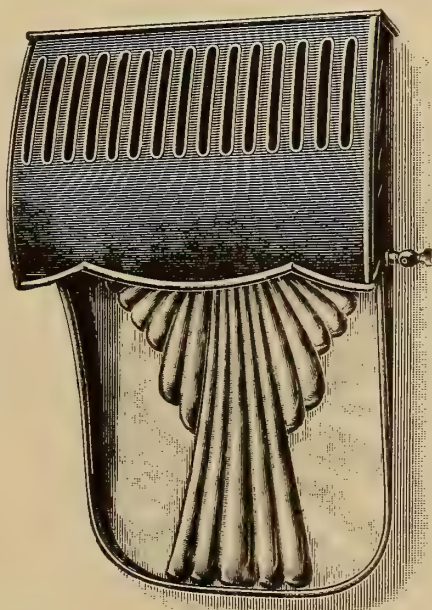


FIG. 3

latter is prohibited by the police and building regulations of many German cities. With these new wall stoves, it is not necessary to measure exactly the distance of the coupling from the floor, because the stove does not stand on it. Should lead gas pipe be used instead of wrought-iron pipe, it is advisable to hold the stove by means of wall fasteners.

Another advantage of considerable importance lies in the saving of floor space. All old forms of gas heating stoves require a floor space proportionate to their size, and the space between the floor and the stove is made useless. The Junkers wall stove does not occupy any valuable space in the room. It can be attached at any part of the walls wherever desired, and, while it gives a large amount of heat, the size of the stove is comparatively small.

There is another advantage which these wall stoves have, and that is one of sanitary importance. With the old forms of gas stoves, the floor underneath them could not readily be cleaned. Dust, dirt, and unhealthful matter accumulated beneath them, and yet the old form of stove draws the air from the very part of the floor which cannot be cleaned, causing the dust to be drawn up and burned on the surface of the stove, producing a noxious odour, which cannot help being not only disagreeably apparent to the occupants of the apartment, but which surely is unhealthful. By hanging the stove against the wall at some height above the floor, it is possible to clean the entire floor and prevent accumulations of dirt and dust.

A further advantage consists in the more uniform warming of the apartment. With all forms of stoves which stand on legs, the floor underneath and at the sides of the stove does not receive any heat radiation, and, therefore, remains cold. The reflector provided in Professor Junkers' stoves causes the floor near and in front of the stove to be warmed, and in this way the lower strata also

are warmed. This, in turn, has a tendency to warm the air of the room more uniformly.

The appearance of these new stoves is quite different from that of the older gas stoves standing on a floor, and it is possible to design and construct a large variety of quite ornamental, pleasing, and novel forms. The stoves can be used in any room having a gas supply and a chimney flue. They are particularly useful in supplementing existing heating systems, for instance, during protracted unusually cold spells; also in apartments which are only seldom used or occupied, but which sometimes have to be quickly heated.

It is hardly necessary to point out that the general advantages of all gas heating stoves, as compared with coal stoves, apply also to the Junkers wall stoves.

The Junkers stoves, as shown in Fig. 2, are made in two sizes, requiring a $\frac{3}{8}$ -inch and a $\frac{1}{2}$ -inch gas supply, respectively, using about 17 and 31 cubic feet of gas per hour under a pressure of the gas of twelve-tenths inch of water. They heat rooms of 1400 and 2800 cubic feet capacity to about 67 degrees Fahr.

The wall stove shown in Fig. 3 is also made in two sizes, of the capacity just stated, while the stove in Fig. 4 is made of one size, requiring a $\frac{3}{8}$ -inch gas supply and using about 17 cubic feet of gas per hour. Of course, the figures quoted regarding gas consumption and heating capacity are merely approximate, for much would depend upon the thickness and material of the walls and partitions, upon the number, size and tightness of the windows and doors, upon the relative position of the room with regard to the points of the compass, upon whether the floor has a cellar under it, or whether the room underneath is heated, etc.

In connection with these stoves, Professor Junkers has invented a novel form of automatically closing gas valve, the object of which is to prevent any unburned gas from es-

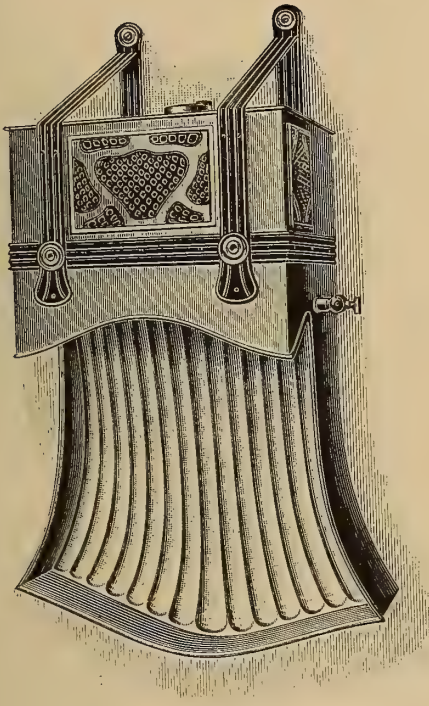


FIG. 4

caping at the burner. This valve is shown in Fig. 5. The left part of the illustration shows it when closed and the right part when opened. Behind the gas cock *a* there is an automatic valve placed in the gas service and normally kept closed by means of a spring. When lighting the stove, the cock *a* is first opened and a lighted match is applied to the burner; at the same time the handle *b* of the automatic valve is turned to

the left and is held in that position for a few moments until the ratchet *c* catches the projection *d*. This holds the automatic valve *b* open as long as the flame is burning. As soon, however, as the flame is extinguished from any cause whatsoever, the ratchet *c* recedes from its position, owing to cooling off, and leaves the projection *d* free, and im-

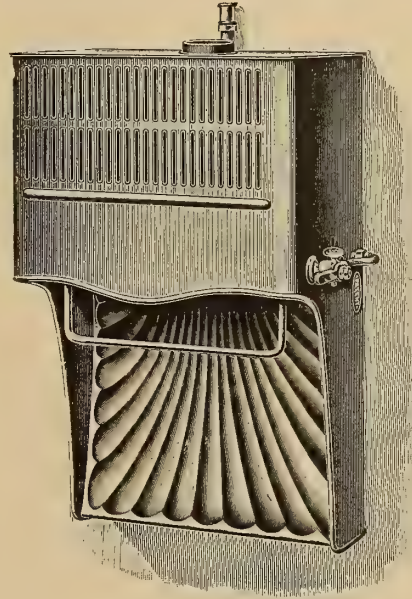
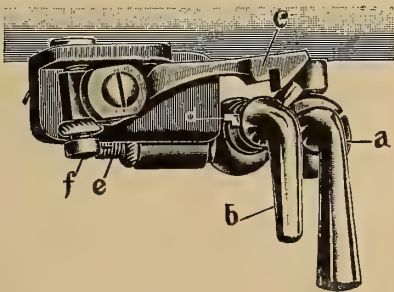
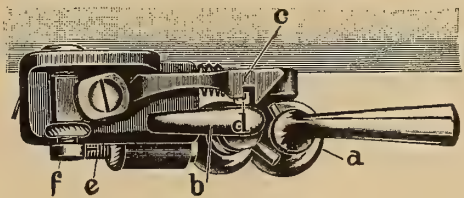


FIG. 6.—THE JUNKERS SWIVEL BURNER

mediately the spring acts and closes the valve. In order to shut off a gas stove, it is simply necessary to close the cock *a*.



CLOSED



OPEN

FIG. 5.—THE JUNKERS AUTOMATIC GAS VALVE

By using this automatic valve, all danger of gas explosion or gas asphyxiation caused by carelessness or accident is done away with. Whether the gas cock is opened carelessly by children, or whether, after the stove has been lit, the light is extinguished either by a gust of wind or by closing the main shutoff in the cellar, the automatic valve works instantaneously, closing off the supply at the stove.

Another device of Professor Junkers is the swivel burner shown in Fig. 6. All his heating stoves may be supplied at an additional cost with the swivel burner, as well as with the automatic closing gas valve. The swivel burner is so arranged that it may be turned downward by a lever handle at the side of the stove. This is done before the gas cock is opened.

By doing this the entire burner is completely exposed and conveniently accessible, but the gas supply to the same is partly throttled. In this way he accomplishes a quiet lighting of the burner without explosion or noise, and the flames burn small until the swivel burner is again turned upward, whereby the gas supply is opened full. The arrangement of a swivel burner offers the advantage that gases of combustion cannot get into the apartment, no matter how the burner stands, for even in its downward position the burner does not project beyond the front of the stove, so that the gases of combustion will still escape vertically to the chimney flue.

The Junkers wall stoves are sold in Germany at prices varying from \$5 to \$35, according to their size.

GAS VS. ELECTRICITY

A QUESTION OF ECONOMY

By Geoffrey M. Gill

IN his article on "Advertising in Connection With Electricity Supply," in the September number of CASSIER'S MAGAZINE, Mr. Arthur A. Day lays great stress on the importance of making known to the public the many advantages of electricity.

Granted that there are advantages attached to the use of electricity supply, yet all those of any importance are on the side of the consumer of gas. I refer especially to the far greater cheapness of the older illuminant, so much so, that people hearing the comparison would hardly credit the possibility of there being so great a difference.

To make this clear, let us take a few figures from the Encyclopædia Britannica. Professor Fleming, one of the greatest authorities on the

theory and practice of electric lighting, states that a Board of Trade unit of electricity will keep an average 16-candle-power lamp going for eighteen hours. On the other side of the question we rely on Prof. Vivian Lewes, through the medium of the same publication, for the statement that 1000 cubic feet of gas will keep a 60-candle incandescent gas burner going for 286 hours.

Now, taking electricity at 4d. per unit and gas at 2s. 6d. per 1000 cubic feet,—the average price in London,—we find that with electricity we get 288 candle-hours at a cost of 4d., whilst with gas we get 17,160 candle-hours at a cost of 2s. 6d. Reducing these figures to one common standard, we find that one penny will procure 72 candle-hours with electricity and 572 candle-hours with

gas; that is to say, for the actual light given, electricity is eight times more expensive than gas.

These figures, based on the most reliable authorities, are convincing proof that gas for illuminating purposes possesses in a marked degree the greatest advantage,—that of cheapness. Moreover, for heating, in stoves and other domestic appliances, I have it, on the authority of the "Harmsworth Encyclopedia," that with gas at 3s. per 1000 and electricity at 1½d. per unit (reduced price for day users of current), gas is no less than seven times the cheaper of the two; this the writer has proved to his own satisfaction by actual experiment.

For power purposes, again we find that gas is the cheaper, as it has been proved in numerous cases that 15 cubic feet of town gas will produce 1 horse-power, whilst with electricity it is generally admitted that it takes $\frac{3}{4}$ unit to give the same amount of power, so that with gas at 2s. per 1000,—the cost to power users in two of the three metropolitan companies,—and electricity at 1d. per unit, we find that the amount of power that costs 0.75d. with electricity can be produced for 0.36d. by gas. These actual figures have been given so that it may be made quite clear that gas supply is incomparably superior to electricity supply in this most important of all particulars.

This being so, one sentence of Mr. Day's article strikes one as being peculiarly vague. He says that "before any method of advertising is adopted in connection with electricity supply, the person, or persons, governing such supply should be quite sure of being prepared to sell current at a rate which would make its use distinctly advantageous to the consumer."

How, might I ask, is the unfor-

tunate electrical engineer to undertake such a task? How is he to reduce his price for lighting by 800 per cent., for heating by 700 per cent., for power by 100 per cent.? At present it is a matter of absolute impossibility to supply electricity at a price which would show any advantage to the consumer. It is an easy matter to make statements, but it is quite a different matter to substantiate one's statements with actual figures.

Mr. Day's statements of the many advantages of electric light are not borne out by the experience of the Gas Light & Coke Company, whose chairman asserted at the half-yearly meeting that they have displaced electricity in more than a thousand cases during the last year; neither do they agree with the same company's increase of 13,400 in the number of consumers during the same period.

The advantages usually claimed for electric light are its cleanliness, its convenience, combined with a negative effect upon the purity of the air. Now, if we consider for a moment what a small amount of dirt is produced by an incandescent gas burner, and what a small amount of trouble it is to turn up a by-pass tap, or even to light the gas, the thought of attaching any real value to such minute advantages should be considered quite out of place, whilst, with reference to the purity of the air, I cannot do better than state, on the authority of the "Lancet," the great medical journal, that the vitiating effect of a gas burner upon the air of a room, assuming that the gas is being burnt in a proper manner, is practicably a negligible quantity. At any rate, it must be admitted by any unprejudiced person that such trifling advantages are completely outweighed by the far greater economy of the older illuminant.

GETTING NEW BUSINESS AND HOLDING THE OLD

AS APPLIED TO ELECTRIC CENTRAL STATIONS

By R. L. Goodale

How to hold business after you have got it is quite as important a matter as first getting it. But to this many station managers have given little thought. Mr. Goodale makes forceful reference to it in the following article, the seventh of the "New Business" series, which began in the April number.—The Editor.

THE subject of getting new business in electric lighting and power companies which has become so popular is the outgrowth of modern methods of business applied to a line of business that for many years has devoted most of its energies to technical details, and which has at last awakened to the fact that there are very productive fields for the sale of current that need only the magic of solicitation to develop.

These new avenues lead the central station management into fields that not only add greatly to the earning power of the company, but help to broaden out many a peak that was only a source of worry and not of income.

With all that is being written and said about business-getting methods, we should not overlook the equally important matter of business-holding methods, and though the operating departments often scoff at the new business-getting departments and claim that they are only a fad, yet most of us believe and know that business-getting is the ripe development of well-organized business.

In a discussion of business-getting I do not think we should overlook business-holding, as I believe that they are so closely allied that no company can overlook either and succeed. I have read with a great deal of interest many of the recent articles in the electrical papers in regard to the different business-getting methods used, and it seems to

me that the central station managements that need the most help and advice in this way are those in small plants. I do not think that large central stations which can, and do, employ the best business talent to manage their affairs get much out of most of the matter printed, as local conditions have such a strong effect on different methods of advertising and selling. What succeeds in one place succeeds through the strong personality and insight of a particular man, or group of men, who are in close touch with every phase of the local conditions.

We have learned much in the past from our competitors, the gas companies, when it has been our good or ill fortune to be in competition with them, and I believe that this progressive competition of these same gas companies has been the most important factor in the development of business-getting departments and methods in the electric company.

Central station managers and employees who have had to contend with this competition have learned much, and they have learned it more from the necessity of deeper thought on how to hold the business than how to get it. This is where the more recent methods have started, and, thanks to the publicity that it is being given, I look for great good to come of it to those central stations which have had no gas competition and which have been satisfied to sit and wait for business to come to them, instead of getting out and go-

ing after the business, as any other progressive manufacturing concern would do. A central station is a manufacturing concern, selling to some or all of the people of a community a product that can be utilized in a great many ways, and it is for the central station management's ingenuity and ability to find the greatest number of ways by which all of the people can be reached.

The old country store is typical of many a central station management. It is the only place to get the thing desired, and so the proprietor sits on an empty barrel and whittles a stick and waits for his customer to come to him. If he is busy, possibly gossiping with a customer or friend, and some one comes in, he lets him wait. The customer buys if he has to have the article, but he probably does not if he can get along without it.

What most small central stations want is not expensive advertising campaigns, but more "ginger," and when they begin to wake up, as they are doing now, we will hear of fewer companies that harvest a crop of complaints and more that are good, paying investments.

I believe that with any company the most important factor in getting new business and holding the old is establishing the confidence of the people in the company, in impressing on them the fact that they are getting a square deal, and I do not know of anything that will help to do this more than courteous consideration and treatment to the customer, whether he comes to make a purchase of an appliance, or sign up for lights, or whether he comes to make a complaint for which you know there is no reason. I do not believe that, as a general thing, enough consideration is given to a consumer's complaint.

The complaint is usually received not by the best and most tactful man that the company can secure, but by anyone down to the office boy. So many complaints can be rectified if

the employee of the company will only give all such as much consideration as he will give his best friend, and if the complaint man is tactful, he can often satisfy a customer in a few minutes, while the latter never would be satisfied if he were laughed at, as he is so often. I do not believe that a customer can be given too much consideration, and I make this statement in the face of the fact that the greater the complaint, the more unreasonable is likely to be the cause of it. Once you shake the people's confidence in you, then your troubles begin. Remember that you are not looking for trouble, but for more business.

I believe that the time is past for charging exorbitant rates, and today sees the re-rating of many a lighting contract that could be renewed at the old rate. Experience has shown that a lower rate for longer hours of burning has not cut down the income, but has increased it; the peak loads have had only the average healthy increase, while the breadth of them has surprised many an enterprising management. Make your rates such that your consumer gets a greater advantage with the number of hours of burning; when you do, you will have more money with which to satisfy stockholders and make progressive extensions.

The subject of electric signs is so extensive that it is impossible to do it justice without giving it the full allowance of a paper by itself, but from the central station management's standpoint, it is an excellent field of profit, as it increases the output with little, if any, extra line expense, and adds a large amount to a merchant's bill for light every month without a complaint from him. If put on a flat rate and burned for six hours, or at the very least four hours a night, signs help to broaden the peak that means money instead of trouble.

The subject of free signs is a much-discussed subject, especially by the sign manufacturing people, and

it is certainly reasonable that if an expenditure of \$75 in a sign will bring in double that amount in income in a year, even at one-half the regular rates, it is a good thing. But many a central station management is forced into making line extensions that often require a big outlay, and they do not always feel that they can put aside enough money to furnish free signs for all who ask for them. I believe the more reasonable way of starting the sign proposition is to put up a big, attractive sign for a progressive merchant in your town, and then, if necessary, pay for a part of it.

The man who advertises is easily approached on the matter of an electric sign to advertise his business, or name. Go after every merchant in your town, and all I have to say is that while the work done during one year may not bring direct results in that year, you may live in hopes, and you will find that by keeping constantly at it, in a year or two you will be astonished at the returns you will get from the first year's work.

A sign bought by the central station and hung for a merchant, the merchant paying for it in monthly installments with his bill, say on a two years' contract, will not be difficult to sell, and even good signs will be replaced at the end of the first two years by better and larger signs.

Do not neglect your small motor installations or your large ones, either. I do not think there is any better method of getting this business than to have a number of small motors, as well as a couple of larger ones, in stock and using them for demonstration purposes. Put them in on a very nominal flat rate for a thirty, sixty or ninety days' trial; put a meter on them to get a line on the use, and then you have something to go on, without being obliged to guess at the amount of current the prospective customer will use.

Suggestions for getting new business are crowded upon us every day

by our friends, the electrical supply manufacturers. I believe that very few of the current-using devices are not worth at least trying. Even if a central station does not deal in the articles bought, they will have very little trouble in placing and selling such samples to good advantage to themselves. If you cannot sell them, at least demonstrate to everyone who can use them that you have something that will increase their sales or cut down their expenses. You cannot expect to have all of your customers coming at you all the time, asking you if you cannot supply them with some electric device. You have to go out after them and show them.

Your commercial lighting is important, and your power business is valuable, so do not overlook either; but remember that your residence lighting is the bulk of your business, in most cases, and so do not overlook that, either. Try, in every way possible, to get your customer to use more current, but do not misdirect your efforts, as much good time can be wasted in this way. The subject of misdirected effort reminds me of a manager in a small town who spent the best part of his time one summer in placing three small motors to run three family washing machines. This required much effort, as the motors cost the customers about \$30 apiece, and after they were installed they probably brought in the income from 2 kilowatts a month in current.

I believe there is no field that is as large and can be cultivated as easily as the field that is open to electric laundry irons for family use. A laundry iron of about six pounds, using approximately 500 watts per hour, will cost about a dollar a month to operate in an average family, and I should like to know of any one appliance that can be so generally placed that will add \$12 in income per year per consumer, the income being derived from the maximum rate on a day load. The

man who spends all summer putting out three \$30 appliances that will bring in \$9 a year in income ought to be able to put out at least twenty electric irons at \$4 each, and these irons would bring him in about \$250 of income a year. If your field is large, there is no reason why you cannot install from 100 to 200 irons the first year, and if you do, you will not find it as difficult to treble the number the second year as it was to sell the first year's deliveries.

I do not know of any one article that, when placed, will be used more constantly or that will give more comfort to an overworked housewife than the electric laundry iron. After once placing the iron, which should be done on about a thirty days' free trial proposition, the installation should be carefully watched and at least enough attention should be paid to the prospective users so that they will thoroughly understand the iron and the most economical use of it. Trouble with the irons and cords should be promptly attended to; it usually occurs in the midst of a big ironing, with no coal stove going. Also follow up your iron users and see that they keep using the irons, or if they do not, at least find out what the trouble is and have it attended to without delay.

As the season is pretty well advanced at this time of the year, advertising is not of very much avail; but if you have waited till summer before putting out irons, take them out and deliver them to your customers, using personal solicitation to place them. There is nothing, to my mind, that places an iron more quickly than personal solicitation and demonstration in the customer's house, and if the installation is followed up, very few of the irons will ever come back.

Don't lay up trouble for yourself by putting out "any old iron," but try them all out and install the one that is going to heat quickly and evenly (if there is any difference, the point should heat first and hottest);

also use a good cord and plug attachment that can be detached from the iron quickly and easily when the iron gets too hot, and a heating unit that can be renewed easily when burned out and at as small expense as is possible.

You can devote the best part of your time to the electric laundry iron, but that is no reason why you should give it all your attention; but the beginning of summer is the most opportune time to install electric irons. At that time of the year the bills for current are down, and if they are below the minimum guarantee, the consumer can see very little, if any, difference in his bill.

Forceful advertising at the beginning of the hot season is one of the very best ways of starting your campaign, but it should bear more strongly on the subject of the discomfort of a hot fire to heat irons with and the attendant exhaustion occasioned thereby than to expend too much space on the iron and its description. If the consumers once receive the suggestion strongly of the discomforts of a hot kitchen or laundry fire on ironing day, and that the heat is sapping strength and vitality, they will be in a good frame of mind to meet the advances of a solicitor when he approaches them with the proposition to install an iron free for thirty days' trial. After installing the irons, keep after them and see that they thoroughly understand the iron and how to use it; only then can they give it a fair trial.

This matter of advertising laundry irons leads me up to the subject of advertising. As you are a manufacturing concern, you must keep your product constantly before the people; make your newspaper advertising as forceful and catchy as you can, but change your copy often, and when you are advertising one of your many current-using devices, keep at it till you feel that it has accomplished its result, or that the season is past when the device can be used to advantage.

Some general advertising should be used, and any novelty that will attract and hold attention will accomplish good results. Don't deluge your customers with too much advertising matter, but make it good, as attractive as possible, something that can be used and saved, or that will attract attention for its artistic value. Make your statements as concise as possible, and yet strong and clear enough so that they will suggest a train of thought to your customer's mind. Advertising matter of the folder or calendar order should be sent by post and not delivered; more attention will be paid to a mailed circular at a residence than it will at a shop or an office.

Your novelties can be distributed by the ever-present small boy, and when he fails to attract attention with them, it will be time to shut up shop.

Keep your company and business constantly before the people. Get the best location possible, with all of the show-window space possible, and space in the office for the accommodation of the public, whether they are waiting for a car or coming in to look at appliances or to buy them. Have a good show-room, and don't crowd it with all sorts of things in all sorts of places. Keep it in order, so that when a customer is looking at a given article, he will not be bewildered with a lot of stuff that will only distract his attention.

As light is the best advertising medium, light up, and make your office and show-rooms the most artistically lighted rooms in the town. As an electric sign will attract the attention of more people to your business location and business, put out an attractive electric sign that will convince every merchant that you believe in it and are willing to demonstrate it by adopting it in your own business.

Use electric fans in your office, not for the convenience and comfort of your office force alone, but for the public, and invite them to come in and cool off.

You cannot convince the public that you are sincere in your statements unless you demonstrate to them that what is good for them is good for you.

If you want to hold your business, give your customers a square deal, and then convince them that they are getting it. Don't hold up your customers on the sale of an appliance, but remember that you are not in the business for the sale of appliances alone, but for the sale of current, and the more appliances you get out, the more current you are going to sell.

Local conditions vary, and one must use his own judgment as to what to push and how to push it; but conditions do not vary when it comes to giving the public a square deal, and the management that does not do so is laying up stores of trouble where he might lay up stores of friends.

When you want more business, go out and get it, and be open to suggestions that are thrust upon you every day, as to new and old current-using devices. Use your judgment; don't give away a \$30 motor that will bring in only \$3 of income a year; but if you have to give away a \$4 iron that will bring you in \$12 income in a year, do it.

You cannot get more business and hold the old without good business judgment, and as your local conditions will govern your actions to a great extent, don't take too much advice and adopt methods that seem to have no special reason in them, but have simply been advertised as having succeeded in other places.

THE REALM OF THE FAN BLOWER

By Walter B. Snow



FIG. 1.—AN ELECTRIC MARINE VENTILATING FAN

WITH the possible exception of the steam pump it is doubtful if any other mechanical device has so varied a field of direct application as the fan blower, these two machines really being in the same class, the one handling liquids at pressures measured in pounds, while the other creates movement of air and gases under pressure differences measured in ounces.

Fan blower applications may be broadly divided into two classes:—First, those in which the object is to actually transport the air or gas; and second, those in which the air serves as a medium for the transportation of other materials.

Ventilation and the supply of air for combustion are properly included under the first classification. The conveyance of light material and the transmission of heat or moisture in the air come within the second classification.

Ventilation, whether secured by

natural or artificial means, results only from the creation of a pressure difference between two points such as to cause a flow of the air from the higher to the lower pressure area. In the case of natural ventilating systems maximum efficiency is secured only through the employment of flues and ducts of large area, through which the air flows at low velocity. At best the mechanical efficiency of the heated flue is very low. With a fan, however, much greater pressure differences can be easily created, and smaller pipes with higher air velocities employed. With the fan, the heat expenditure necessary to produce a given air movement is astonishingly less than with natural draught in a flue or chimney.

According to the degree of activity of the occupant the velocity of the air admitted to a room may be high or low, but it is easily regulated where a fan is employed. In the sparsely occupied building the per capita space is large, the air volume required is, therefore, relatively small and the rate of flow may be high. In the crowded hall of audience the minimum of floor space is provided for each occupant and the maximum of air supply is required. Here the utmost refinement is necessary in the tempering and distribution of the air.

In the ordinary building, ventilation is very properly a process of substitution of fresh air for foul air, but the fan does not absolutely control the conditions, for the walls are usually porous and there are leaks around the windows and doors. In the mine, however, with its practically air-tight chambers and its vertical shaft, there is no appreciable inward or outward leakage. All air

which passes through the mine likewise passes through the fan, very positive control being had over its distribution.

As applied for supplying air for the combustion of fuel, a fan blower varies in type according to the character of the furnace. For the production of mechanical draught for steam boilers, under either the forced or induced draught system, the fan may be of ordinary steel plate construction, designed to operate at a maximum pressure of from 1 to $1\frac{1}{2}$ ounces per square inch. Here the fires seldom exceed 10 inches in thickness. On the other hand, in the foundry cupola, with its superimposed charges of fuel and iron aggregating 10 to 15 feet in depth, a pressure ranging from 8 to possibly 16 ounces per square inch is essential to compel the passage of the air through the tortuous channels formed by the mass of material within. The total quantity of air required under these conditions is relatively small, while the type of fan is distinctive, being narrow, of high efficiency and maximum durability, but of only moderate volumetric capacity.

The forge fire and the puddling

furnace present conditions less strenuous; nevertheless they both depend upon the fan blower for successful operation. Aside from its application for blowing the forge fire, a separate fan may be utilized for withdrawing the smoke and gases direct from the forge hoods. At least one instance exists where these gases have been subsequently utilized to heat the air discharged by a blower system for the warming of an adjoining building.

Air under pressure, fed into a stream of gas or atomized oil, insures its satisfactory combustion and application in the arts. Pulverized fuel is burned by thorough admixture with a current of air and subsequent ignition in a suitable furnace.

The transmission of heat or of moisture by means of a fan blower is closely allied with the process of ventilation. In an ordinary fan heating system all of the heating surface is massed at the fan, whence the heated air is forced through ducts to all parts of the building. For normal indoor temperatures with outdoor air at zero, the incoming supply must range in temperature from 100 to 150 degrees, according to the rapid-



FIG. 2—EXHAUSTERS IN A SLASHER ROOM

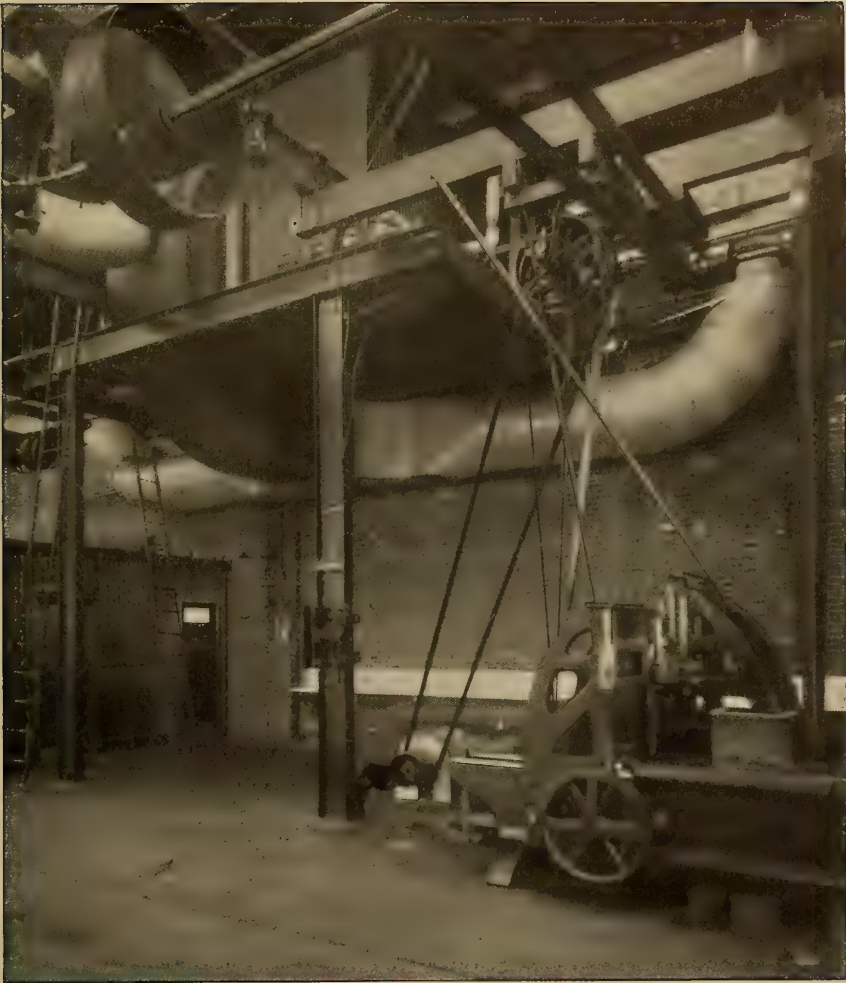


FIG 3.—HOT BLAST APPARATUS SUPPORTED OVERHEAD

ity of air change within the building. The air thus becomes a medium by which the heat is transmitted to distant points.

The process of drying is only an exaggerated case of heating in which the temperature to be maintained greatly exceeds that required in a well-ventilated room. A supply of air sufficient to change the volume once in 8 to 15 minutes in an ordinary structure is all that is necessary to meet the conditions of good heating and ventilation, but a supply equivalent to a complete change in

the free spaces within the dry-room sixty or more times per hour is required in the lumber drying kiln. The temperature in this will range up to 150 or more degrees. Owing to its greatly increased absorptive power the air at this temperature greedily takes up and carries away the moisture in the exposed surfaces. The method of application and the temperature to be maintained depend entirely upon the character of the material to be dried.

Glue and gelatine require low temperatures and ample volume. Knit

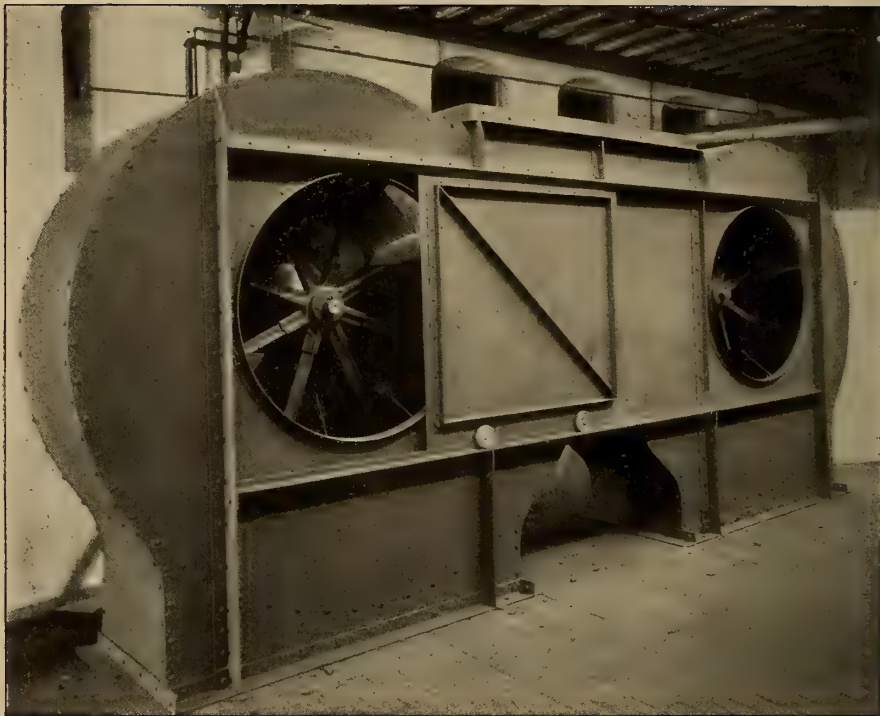


FIG. 4.—A DUPLEX INDUCED DRAUGHT APPARATUS ARRANGED WITH ONE FAN AS A RELAY

goods in the piece are dried by internal application of heated air under pressure which distends the piece, the air escaping through the meshes. Cotton, wool, and the like are spread upon beds formed by covering with netting enclosed boxes into which the hot air is discharged and from which it can escape only through the material above.

The materials now dried by hot blast are legion—asbestos, blood, bricks, and clay, clothespins, eggs, leather, malt, milk curd, gunpowder, hair, soap, stove linings, sweet corn, yarns, and a thousand other products of industry depend upon this process for their successful production.

The process of cooling is essentially the reverse of that employed in heating, but systems which materially lower the temperature of the admitted air require the most careful attention in the matter of distribution and maintenance. Many combined

systems of ventilation and cooling contemplate only a rapid passage of outdoor air through the apartment requiring reduction in temperature. Perceptible air movement has the effect of cooling even with no material change in temperature. The rate of change may be as frequent as once in two minutes in the case of an overheated engine or boiler room. The mistake is frequently made of trying to cool without a sufficiently rapid air change; as a result the air remains so long in transit that it becomes overheated before escape.

Local ventilation and cooling are best secured by the use of an exhaust fan and the proper hooding of the source of offense; but such an arrangement is generally impracticable and a general sweep of air through the room must be substituted.

Closely allied with the cooling process is the prevention or removal of visible moisture in the form of steam. In the paper mill machine room,

with its numerous heated cylinders surrounded by moist paper, a perfect system of prevention and cure includes a hot blast apparatus by means of which heated air is forced into the room and an exhaust fan with hood connection by which the heat and moisture just above the machine are directly and positively removed. The warm air supply to the room absorbs the moisture not directly removed by the exhaust fan and prevents local deposition of moisture.

In the dyehouse the offense of steam production is greatest, and a complete application most essential. The slasher room of the modern cotton mill, provided with a locally applied exhausting system, is kept perfectly clear, in distinct contrast to the older form of construction with so-called natural ventilation. See Fig. 2.

resulting variety in shapes and proportions fit it for application under almost every conceivable condition.

The heating apparatus may be hidden away in the basement of a large building, or, in the open shop, may be supported overhead upon heavy steel construction where it occupies no valuable floor space. See Fig. 3. A mechanical draught apparatus is frequently made duplex in type, as in Fig. 4, so that one fan will always serve as a relay. By the arrangement of easily adjusted dampers one fan may be thrown out of commission and the other into service at a moment's notice.

The advent of electrical means of driving very much simplified the application of the fan blower. An electrically driven fan may now be placed at the most convenient point without extended systems of piping



FIG. 5.—AN EXHAUSTING ARRANGEMENT FOR GRINDING AND POLISHING WHEELS

Fundamentally, the term ventilation is understood to refer to the supply of air for the purpose of respiration, but in its broader sense it applies to any air change which conduces to comfort. The flexibility in the design of the fan blower and the

and with minimum loss through friction in pipes. Marine installations have called for special designs, in many of which a fan is arranged to be suspended from the deck above, as in Fig. 1, and driven by direct-connected motor attached to the side

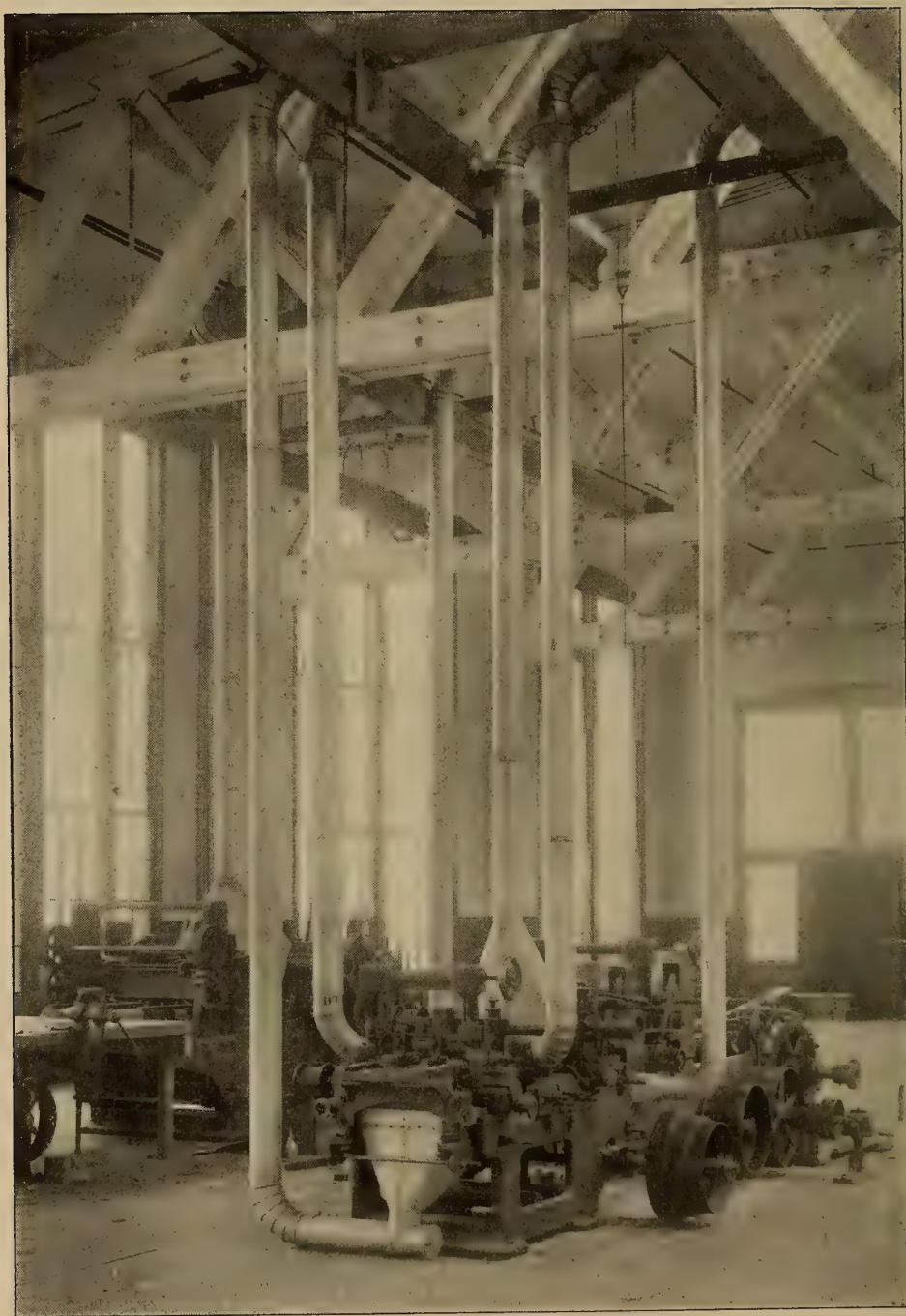


FIG. 6.—EXHAUSTING ARRANGEMENT IN A PLANING MILL

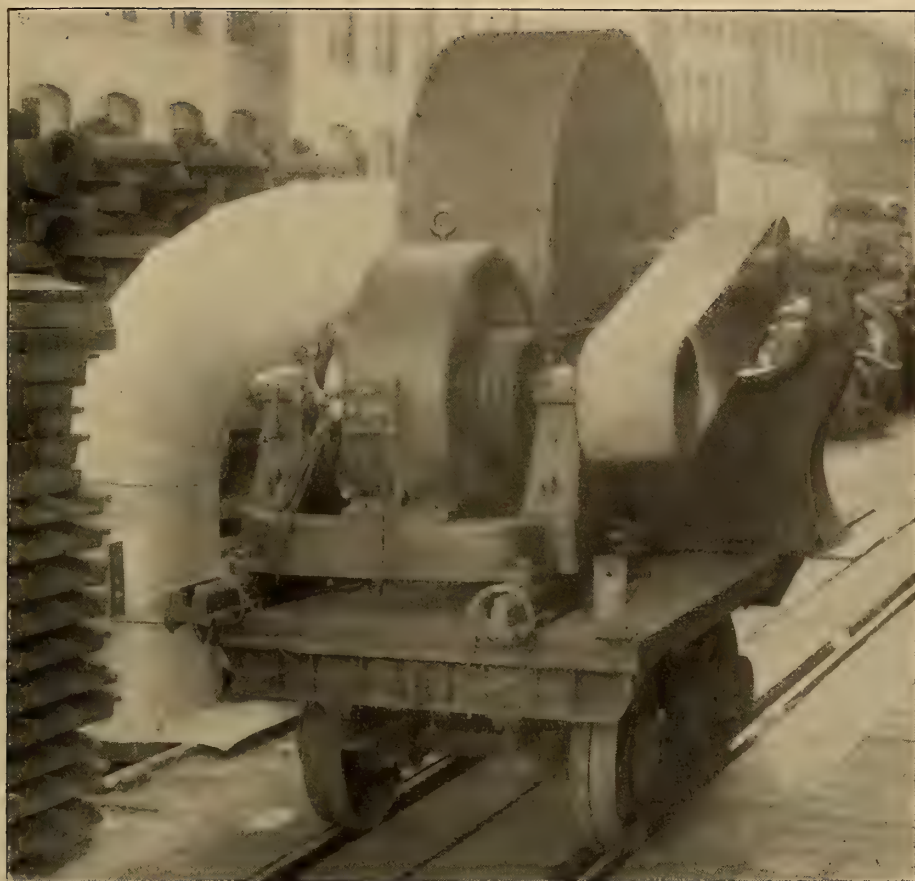


FIG. 7.—A PORTABLE FAN AND MOTOR FOR LOCAL VENTILATION OF A STEAM TUNNEL

plate. For local or temporary application nothing can exceed the convenience of the motor-driven fan blower which may be used for the ventilation of tunnels, excavations and the like. It is distinctly portable, renders ventilation positive at the most critical points, and avoids long piping connections. On ship-board portable electric blowers fitted with flexible pipe connections are employed for temporary ventilation of close spaces in the hold.

In modern installations the production and distribution of illuminating gas calls for gas blowers and exhausters which blow the generators and transport the gas through long distances or from holder to

holder. With this arrangement the works may be located at the most convenient point outside the city limits and the gas may be forced through relatively small pipes under considerable pressure to all parts of the city. Local boosting of pressure may be very simply provided by small blowers. This method of increasing the pressure is almost invaluable in localities where the consumption has outgrown the capacity of the pipes.

In every industry producing relatively light particles of refuse material such as shavings, sawdust, lint, dust from polishing and grinding wheels, tumbling barrels, and the like, the equipment is not complete

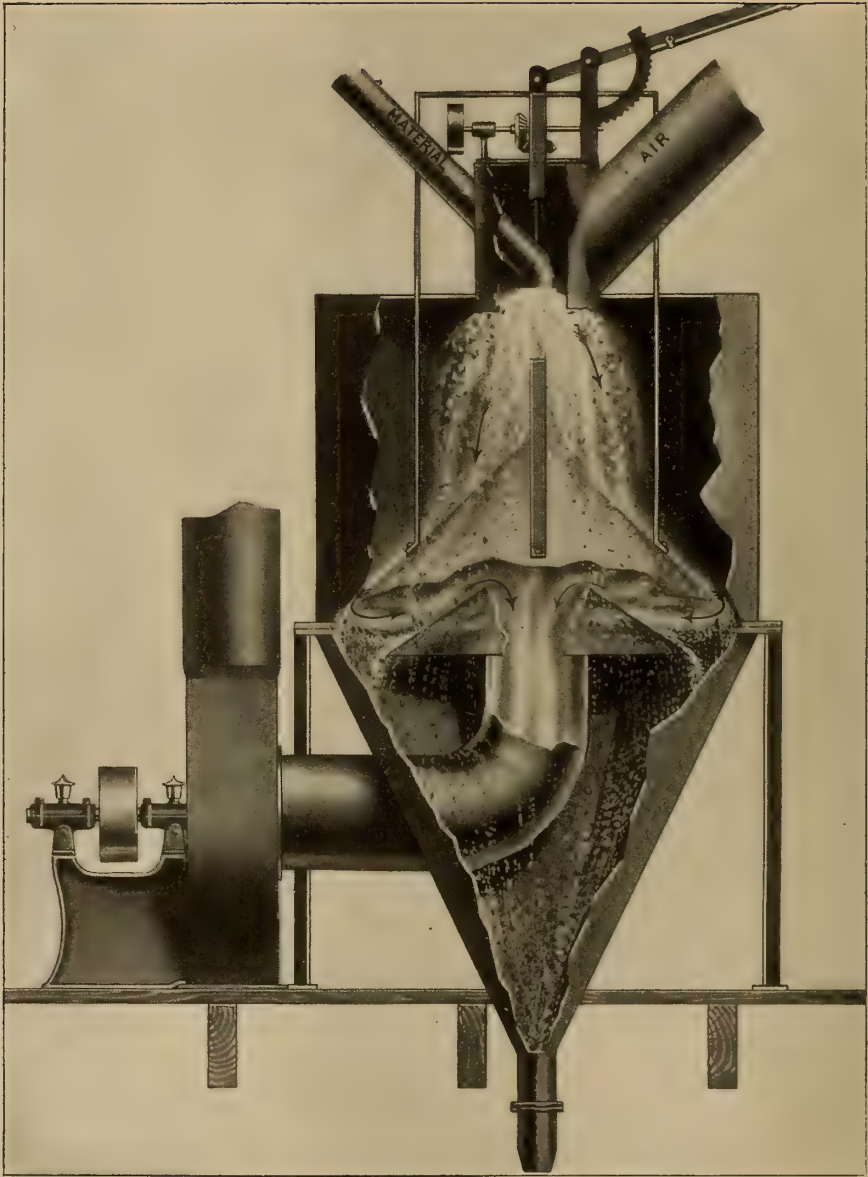


FIG. 8.—A PNEUMATIC SEPARATING DEVICE FOR FINE, LIGHT MATERIALS

without an exhaust fan and dust collector, Fig. 6, by means of which the air is utilized as a medium for conveying the fine particles away from the source of production and quietly depositing them at a distant and convenient point. The modern buffing and polishing room, Fig. 5, the foundry snagging room, the sand

blast apartment, all are made healthy with a clear atmosphere by the introduction of the fan.

Not only does such an arrangement prove effective in the matter of health and cleanliness, but it is an important factor in reducing the cost of manual labour which would otherwise be required for the re-

moval of the material. This is particularly true in the case of systems primarily installed for the conveyance of materials. Such, for instance, is an installation of fan, piping, and suitable switches for transporting cotton, wool, rags and the like. The fan wheel is of special construction to prevent clogging, and the system is so arranged that wet wool, for instance, may be passed from washers to dryers, and from dryers to cards, or cotton may be taken from the pickers, transported to the dye house, thence to the dry room and back to the pickers or to the card room. The fan serves to open up, clean, and dry the material as it passes, and an expensive system of trucking is eliminated.

No modern cotton gin is complete without a fan which draws the cotton direct from the wagon, and continues the process through the gin to the storage bins. Pulp chips in the sulphite mill, tan-bark, brewery grain, coffee, coke breeze, and like materials are economically handled by the same process.

The susceptibility of any material to movement under these conditions depends upon the relation of its weight to its superficial area. The open newspaper is among the first to

go flying in the air; it better resists the wind when rolled in a wad, and still better withstands such action when compressed into a hard ball. A rocky ledge remains immovable in the wildest hurricane, but the gentlest zephyr will waft it away if ground to impalpable powder.

The pneumatic separator and collector successfully applies the principles thus taught by nature. In such a system, Fig. 8, a current of air, set in motion by an exhaust fan, is the vehicle for conveying the fine particles; intensifying the current by restricting the area of passage enables it to pick up the large pieces. Thus the fineness of product is controlled; the finest pass through the fan, the coarser particles by-pass and may be returned to the mill for re-grinding. Various types of air separators, or graders, and collectors handle all classes of pulverized material from mill, pulverizer, or crusher.

The limits of the realm of the fan blower cannot be established, its boundaries are constantly increasing, new processes and industries depend upon it for successful operation, old applications are improved by its introduction; it is a boon to all mankind.



THE APPRENTICESHIP SYSTEM IN AMERICA

ITS RELATION TO TRADE SCHOOLS AND THE INFLUENCE OF EACH ON AMERICAN EXPORTS

By Luther D. Burlingame, Chief Draughtsman of the Brown & Sharpe Mfg. Co.,
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TO consider the bearing of education and skill on the foreign trade of a country may seem a long step from cause to effect. It is, however, an important one, and in considering the question of American progress in the markets of the world, it should be given due weight. We should know whether the present gain in America's foreign commerce is due to the vastness of her natural resources, resulting in the exportation of raw material and roughly finished material only, or whether the country is developing skill among its workmen that is extending the sale of finished products abroad on the basis of their superior quality, as shown by their design and workmanship. We should know whether we are pursuing such a policy in training our youth as to develop the highest degree of efficiency and skill in those trades on which the future prosperity of the country and its standing abroad must be based. The training of skilled workmen is one of the great problems of this industrial age, and the nation that, in the largest measure, solves this problem successfully, will attain the highest success.

An article by F. A. Vanderlip was recently published in the "World's Work," leaving the impression in the mind of the reader that cheapness rather than high quality is what sells American goods abroad. This, he argues, is because American workmen are not so well trained, being less skillful than those in corresponding trades in other

countries. He lays the lack of skill in America largely to the extensive use of automatic machines and operations, teaching the workman one thing only and leaving him helpless when any hand-skill is required or thinking is to be done. The remedy, he points out, is in the establishment of trade schools on the line of the "German Continuation Schools." Mr. Vanderlip discusses especially the mechanical trades, properly emphasizing these, as they underlie all modern progress in manufactures. Dr. Louis Bell also sounds a note of warning along similar lines in a leading article in "The Engineering Magazine" for September.

The statements and conclusions of both of these writers seem far too sweeping to many that have had experience with manufactures on both sides of the Atlantic. For example, in the machine tool industry, most of the modern types of machines have been either invented or brought to their present state of perfection in America, and have been, and still are being, sold abroad not on account of their cheapness, but because of the merit of their design and the excellence of their workmanship. In many cases the prices of the American machines are materially higher than those of the competing machines in the countries where sold. Those makers abroad who have produced the most successful tools of this character have modeled largely on American lines; not only this, but in many cases their engineers have visited America and made a careful study of American methods,

adopting them for their own work, and they have employed American managers and designers to develop what they by so doing recognize to be superior in workmanship and design.

At the Paris Exposition in 1900, among the large number of "Grand Prix" that came to America, one American firm of machine tool builders was rated the highest among all competing countries, points requiring skilled workmanship being prominent in determining the awards; and at the Liege Exposition last year the jury gave the highest possible rating to an exhibit of American machinery, a member of the jury saying that if there were anything higher, it would have been awarded.

Among mechanical products, aside from machine tools, which might be mentioned, that hold the foreign market, in part at least on account of superior workmanship, are gun-making machinery, shoe machinery, sewing machines, barbers' clippers, typewriters, cash registers, machinists' tools, dental instruments, printing presses, etc., these being mentioned at random as representative of a large class. According to the report of the United States Bureau of Manufactures, American machinery to the value of over \$82,000,000 was exported in 1904.

While it may be true that America has not yet developed the highest grade of artistic skill, as far as paintings, decorations, statuary, etc., are concerned, when it comes to machinery, experts have given the highest praise to American designs and workmanship. If successful American manufacture is based on the extensive use of automatic machinery, such machinery requiring the highest degree of skill in its design, manufacture, and maintenance, it is evidence in itself that America is not lacking or falling behind in skill. It is also true that specialists, concentrating on one line of manufacture, directing all their energies to the perfection of that product, can

be expected to bring it to a higher state of excellence than if the same workmen were expected to build anything from a cash register to a locomotive. This concentration and specializing is distinctively the American method,—a method well championed by Mr. Alex. E. Outerbridge, Jr., in the October number of this magazine.

There is often a tendency to overlook home advantages in grasping for those at a distance. Competent observers have repeatedly shown that, class for class, American workers are brighter, better educated, and better paid than those abroad. All this results in a higher standard of living and, its natural accompaniment, a higher grade of skill. An indication of this is shown in the extensive reading of mechanical and technical papers by the American workman, a thing almost unknown among the same class elsewhere. Another indication is in the number of patents taken out for inventions by American workmen. The gulf between the workman and the technically educated engineer abroad is much wider and harder to bridge than in America. There is less willingness to consult with, and get help from, the workman by those whose technical training has often been on such lines as to leave them impractical themselves and contemptuous of the suggestions of those actually doing the work. The natural result is a lack of efficiency and a lowering in the standard of skill.

The question as to whether America has in the past excelled in workmanship is, however, of secondary importance to that as to how, in the future, such skill can best be cultivated as to give us the largest possible share in the world's progress. As a means of developing such skill, I wish to urge the importance of the apprenticeship system and the need of its future extension, because the way to learn how to do a thing is to do it and then to do it over and over again until it becomes second

nature to do it correctly and quickly. This is skill and it is the skillful workman who turns out work which, on account of its superiority, holds the market at home and abroad.

Mr. Vanderlip, in common with many other writers, assumes at the start that there is no apprenticeship system at the present time, and bases his recommendations of a remedy on such a supposition. This seems to show a lack of investigation as to facts, for whenever an investigation has been made, it has shown that there exists in our mechanical trades a well-established system of apprenticeship adapted to modern needs and becoming every year more and more a factor in the production of skilled workmen. Thanks to this and the many helpful forms of industrial training, American youth are to-day receiving a training that is developing a higher and higher degree of skill.

It may be true that there is little of the old form of apprenticeship remaining where a boy was indentured to a master, living and working with him during his minority. This would not be possible with the changed conditions, but that which has taken its place is far better suited to the requirements of modern manufacturing and gives the boy at least an equal, and, in many cases, a much larger, opportunity to learn the business in which he is engaged. In almost all large centres of manufacture, schools now exist which apprentices can attend during evenings, studying those branches helpful in their trade which they do not get in their daily work. Some of the employers require a study of mathematics, draughting, and other helpful subjects as a part of the course of apprenticeship. The tendency of such an apprenticeship training is to preserve the balance between head and hand work, and an intelligent boy who finds it necessary to leave school after completing the grammar school course need not feel that he is seriously handicapped, for with

evening study he can acquire additional knowledge, assimilating it with his daily work in a way to be the most useful in the development of skill.

There are those who feel that the tendency is now too much towards the cultivation of the mind compared with a training to develop manual dexterity. Many a boy has, in the past, received a valuable training on the farm, where the varied needs furnished work that cultivated ingenuity and resourcefulness, these being supplemented by the limited training at the winter school. A judgment of the proper proportion of things was thus developed, so that many men have attained a high degree of success in life due to such a training. Modern city life offers less opportunity for the cultivation of skill in the varied pursuits of home life than was possible under these earlier conditions, and besides, the thoughts of our people have been largely directed to school training as that necessary for a successful life. This in itself would have a tendency in the direction of a falling-off in skill among workmen if not counteracted by the introduction of other methods of training.

Such methods have been found in the development of the apprenticeship system and of manual training and industrial schools. These schools are doing a necessary and useful work, but they cannot pretend to give trade skill to any such extent as experience in the shop would give, and that is where the apprenticeship system finds its field of usefulness. It is true that no system of apprenticeship can be made to fit all cases, and schools aiming to give trade skill have entered the field and proved their fitness to meet many special conditions. As an example I would mention the work among the negroes at Tuskegee, in Alabama, where trades are taught under school organization. The artisan school recently started at Syracuse, New York, of which Prof. John E. Sweet

is the prime mover, aims also at real trade teaching. This school has for its object the teaching of the machinist's and allied trades by doing commercial work, alternated with mental training. There are also schools to teach shop men how to read drawings, schools to teach draughtsmen shop work, schools to teach pattern makers moulding, etc., etc. Many such schools, as Mr. Vanderlip proposes, schools to train those already employed so that they may be more efficient in their work and better fitted for promotion, are in successful operation in America. Correspondence schools also are ready to give instruction in all branches of manufacturing enterprise.

None of these varied substitutes can, however, fully take the place of a system of apprenticeship, a system in which a boy is indentured to some reliable up-to-date concern for a term of years and pledges himself to serve faithfully during that time. Some form of evening industrial school training is now within reach of boys serving such an apprenticeship and will give them the help needed to round out their practical experience in the shop. Here is where an increase in the number of "Continuation Schools" would give additional means of training, serving as the aid and auxiliary of the apprenticeship system and not as a substitute for it.

Mr. Fred. J. Miller, editor of the "American Machinist," writing several years ago of his personal observation of the conditions in Germany, said:—

"One gets the impression that technical education is somewhat overdone,—that too much dependence is placed upon it and too little importance is attached to practical shop experience by those who direct industrial operations. Many such men (technically educated) are found in the shops who know a lot that is to be found in books, but nothing whatever of skilled workshop manipulations, and they seem to have been

deprived of the power of acquiring the habit of independent thought."

Among the requisites of a successful system of apprenticeship are:—

Selection of Boys.—There should be a careful selection of boys fitted for the work. This implies a period of trial, during which the boys are tested as to their intelligence, application, accuracy, interest, and other desirable qualifications, and those candidates who are found lacking are weeded out.

Rate of Pay.—The rate of pay should also be determined beforehand and should be uniform for all, increasing in periods frequently enough to make the boys feel that they are getting ahead. A deposit required at the beginning for the privilege of learning the trade is an assurance of good faith and helps the apprentice and his parents or guardians to take the matter more seriously. Where a worthy candidate cannot advance the required amount, it can be taken from his pay in weekly installments. The payment of a bonus at the end of the service of apprenticeship, if warranted, for faithful service, is an effective incentive to most boys. It helps to keep them to their agreement toward the end of their apprenticeship when they have become valuable to their employers and are likely to have tempting offers from outside. It is very desirable that the boys have some job work from time to time, so that, by exerting themselves, they can make higher wages than their regular apprenticeship rates. This helps to put them on a commercial basis as regards time and gives them an added interest in their work.

Length of Service.—The length of service should be for a period agreed upon beforehand, and should be dependent upon the nature of the trade and the age at which candidates can successfully enter it. In the case of machinist apprentices, where the apprenticeship can be commenced between the ages of 16 and 18, four years have proved a satisfactory term.

while in the case of apprentices in draughting, where it is desirable that they start in when more mature and with a previous school training in the rudiments, two or three years are about all that can be required. It is a help if part of this time can be spent in the machine shop, working a short time in each of the important departments.

Variety of Work.—The kind of work given to the boys should be in such a variety as to give the most varied training possible. The apprentice and his future should be considered as well as the profits to be derived from his services at the time. It is desirable that the schedule should be arranged, in part at least, beforehand, so that it will be definitely known, for example, in the case of the machinist apprentice, how much time will be devoted to lathe work, drilling, milling, assembling, erecting, screw cutting, planing, scraping, bench work, etc.

Outside Study.—If possible, outside study and auxiliary training in evening schools to supplement the work in the shop should be a part of every boy's training. When evening schools are not available or suitable, private instruction or home study can be resorted to. Such study, in addition to the knowledge gained, gives confidence to the student and should be a means of developing character and those qualities that will make a boy feel like holding his head up in the world and taking for himself that social position that some claim is not accorded to the mechanic or other manual worker, so that he will feel no lowering of social standing as compared with clerks and others whose work does not require the same degree of manual skill.

The necessity for this auxiliary training makes a field for the extension of industrial schools to be within reach of more and more workers, and such schools can be of help to both apprentices and operators of machines; the more practical they are made and the more experience with

real work their instructors can have, the more probability there will be of their training the students to meet the needs of manufacturers.

Competent Oversight.—The apprentices should be in charge of a competent man whose duty in whole or in part should be to see that a proper selection is made in hiring new boys. He should look after their general welfare, keeping an oversight of them both inside and outside of the works, encouraging, correcting, and teaching without such a show of paternalism as to take away the boy's self-reliance, but working in sympathy with him and keeping such watchfulness as to see that he gets a fair deal.

In small shops, where but a few apprentices are employed, the superintendent or manager can take this duty upon himself. In the larger works, however, where a large number of apprentices are employed, it becomes important to have a man who can give much, or all, of his time to this work. Every shop, however small, should be looking to the future in the training of boys, by a system of apprenticeship, to shoulder the responsibilities of the work later; and it is to the wide extension of such a policy that we can look for the greatest future development of skill.

Among some notable examples of the modern development of the apprenticeship system in the larger manufactories are those of the Westinghouse Companies, in which the apprentices are classified according to education and previous experience, and this classification determines their course of training. The Baldwin Locomotive Works also classify their apprentices, training each class for some particular one of the various needs of the work. Evening study is required as a part of their course. The General Electric Company also require study as a part of their apprenticeship system, and five hours a week are taken from working time for that purpose. The system in suc-

cessful operation at their Lynn works is well described in an article by M. W. Alexander in the September issue of "Machinery." At the Brown & Sharpe Manufacturing Company's works, the apprenticeship system has been a factor in the success of the business from the start and, as time goes on, is being given more and more the attention that its importance warrants. Many of the most important positions in the works are filled by former apprentices.

Any employer who pursues a policy of promoting the tried men in his employ, thus establishing the feeling that successful endeavour will win

promotion, is building on a solid foundation. In this way boys starting to work in early life and proving capable and faithful, can put themselves in line of promotion sooner than when more time is spent in preliminary outside training. The industrial schools of America should have all the encouragement possible, but should not be held before the youth of the land as giving an adequate substitute for the modern apprenticeship system to develop skill in a given trade; rather both should work hand in hand for the accomplishment of that end.

A PECULIAR CASE OF SPONTANEOUS COMBUSTION

By S. E. Worrell

FOR many years the writer has made a careful study of spontaneous combustion, which probably has been the mysterious cause of many fires. The present case was a peculiar one, owing to the absence of the usual conditions causing spontaneous combustion, such as radiant heat, vegetable oils, or moisture in combination with carbon, as in moist coal in bulk.

Wet sawdust in large quantities frequently becomes very warm in the interior even when exposed to winter weather; in fact the lower the temperature of the atmosphere, the hotter usually the sawdust. But to my knowledge no damage has occurred from these instances which most nearly approach the present incident, of which the following is an accurate record:

On Feb. 17, 1906, two large refrigerator cars of young rose-bushes were received at Hannibal, Missouri, from a nursery in California, for cold storage and general

distribution throughout the surrounding country. They were shipped in wooden cases containing numerous auger holes for ventilation and were carefully packed with wet sphagnum, or California swamp moss, to prevent chafing and to support their vitality.

No ice was put in the cooling tanks, and the covers of these, as well as all other openings in the cars, were closed as tightly as possible. The cars were ten days in transit. The outside temperature was 60 degrees Fahrenheit at the start, and 15 degrees at the end of the trip.

Upon arrival, steam was issuing from every crevice of the cars. Upon removing the tank covers, it rushed out in large volume. The doors were opened and ice was put in the tanks; the free circulation of cold air then soon cooled the contents of the cars.

In unloading it was discovered that some of the two upper layers of boxes were badly damaged by heat,

which naturally was the most intense near the top of the cars. No signs of actual combustion were found, but this would probably have occurred in a short time had not the

cars been quickly cooled. The temperature must have been nearly up to the burning point, as many of the green stems of these plants were black and brittle.



From Other Points of View

Electric Water Heating

James I. Ayer before the National Electric Light Association

FOR heating the general water supply a kitchen boiler of the usual type is used, varying in capacity from ten to thirty gallons, and supplied preferably with a heater contained in the boiler of a maximum of 2000 watts, which may be reduced to 1000 or 500 watts by a controlling switch. Such a boiler should be jacketed with ordinary pipe covering, and, with care, is not necessarily an excessively expensive luxury. A ten-gallon boiler can be heated to 150 degrees F. with approximately $2\frac{1}{2}$ kilowatt-hours, which will answer a very considerable demand throughout the day from a jacketed boiler of that capacity.

For bath water, heaters are supplied to place in the tub, and if of 2000-watt capacity are frequently satisfactory to those who understand in advance that it requires 2000 watts for an hour to raise 20 gallons of water through 40 degrees F.

Radiators for occasional use in bedrooms for short periods are prac-

tical and useful, but should have a capacity of not less than 1000 or 1200 watts to be at all effective, except in the case of small rooms, and should be larger for large rooms. For heating the bathroom many radiators are sold which, to be effective quickly, should have 2000 watts capacity. Of this size, if turned on for fifteen or twenty minutes, they fully accomplish their purpose, and are not expensive to the owner.

The instantaneous hot water heater, to be practical, requires that current supply of 3000 watts and more is available. While for small quantities the cost of operation is not excessive, the service demand is undesirable and it is expensive to install; and as small water heaters are so much more simple and easy to supply, they meet the demand for small requirements.

The service for a family kitchen for the average family for cooking should have capacity of about 3000 watts, and if a kitchen boiler, bath water heater or bathroom radiator is to be included, a double-throw switch can be installed in the kitchen or other convenient place so con-

nected as to throw off the boiler, radiator or bath circuit when the cooking circuit is required, and to avoid extra large service capacity which would otherwise be necessary.

American Coal Production in 1905

E. W. Parker in a United States Geological Survey Report

THE production of coal in the United States in 1905 amounted to 392,919,341 net tons, having a value at the mines of \$476,756,963, surpassing in both quantity and value all previous records in the history of the country. Compared with 1904, the output in 1905 exhibits an increase of 41,102,943 net tons, or over 11 per cent. in quantity, and of \$32,385,942, or over 7 per cent. in value.

Of the total production in 1905, 77,659,850 tons were Pennsylvania anthracite, with a value at the mines of \$141,879,000. The total production of bituminous coal and lignite was 315,259,491 tons, valued at \$334,877,963. The production of anthracite coal in Pennsylvania in 1905 was 4,503,151 tons more than in 1904, while the increase in the production of bituminous coal and lignite was 36,599,882 tons.

The larger part of the increased production in 1905 is credited to the great activity in the iron industry, as is shown by the fact that the amount of coal made into coke increased from 31,278,573 to 42,412,328 tons, and that the larger increases were in the coking coal-producing States and those which furnished fuel to the iron furnaces.

Concrete Without Water

From "The Electric Railway Review"

WHILE as a general principle the best is none too good, there are instances where a modification is justifiable. This is illustrated by the Indianapolis Trac-

tion & Terminal Company, which has made a most interesting experiment in track substructure and demonstrated the practicability of a make-shift method that will be advantageous for emergency construction on city lines where it is desirable not to interrupt traffic. In June, 1905, it was desired to improve a portion of Northwest avenue, but the company did not wish to remove the old rails because they were not yet worn out, nor did the expense of putting the standard concrete substructure under track with old rails seem justified. Under these circumstances the engineer decided to ballast the track with a dry concrete mixture, using the cheapest cement to be had. Accordingly the roadway was excavated and the track lowered to a depth that would permit 6 inches of ballast under the ties when again brought up to grade. The ballast used consisted of 1 part natural cement, $2\frac{1}{2}$ parts sand and 5 parts gravel, mixed dry at the gravel pit, the only moisture in the mixture being that contained in the sand and gravel when taken from the pits. This dry concrete was dumped on the track and tamped under the ties until the track was brought up to the proper grade. This permitted operation of cars during the work, and the track so treated has held its surface and alignment. A careful inspection of this work made in May, 1906, showed that the ballast had absorbed the moisture and had hardened, and that the concrete had about 75 per cent. of the strength to be expected had it been properly mixed.

This experience of the Indianapolis company has been of considerable value to one of the interurban lines running out of the city. One of the smaller towns on the latter was improving its streets, and, to comply with the original specifications, would have required the interurban company to build temporary tracks through the town or suspend traffic. The difficulty was avoided

by the town permitting the use of dry-mixed concrete as ballast, which was done after inspection of the $2\frac{1}{2}$ miles ($1\frac{1}{4}$ miles double track) of track in Indianapolis, which have been described.

Abusing Valves

From "The Valve World"

MANY valves are returned to the manufacturers, after a term of service of uncertain length, by purchasers who claim that the valves are defective in workmanship and not tight. The manufacturer is requested not only to credit the valves returned, but also to bear the expense of taking them out of pipe lines, and of putting the new ones in place. He is likewise expected to bear the cost of transportation both ways.

Undoubtedly there are cases in which valves defective in construction escape detection until they have been in service for a time; but in most cases the criticism that is directed to the manufacturer does not belong to him, and affects his reputation unjustly. When valves that are thus returned as defective have been received by the maker, and carefully examined and tested, it is found, in the great majority of cases, that the leakage was plainly due to the abuse and carelessness of the persons who installed them. It is an easy matter for a practical valve maker, or a good steam fitter, to determine when and how a valve has been abused; and if customers would take a little pains to examine leaky valves before returning them, they would find that in most cases the damage was done by their own men. It appears to us that anyone who has done considerable steam fitting work should be able to determine for himself whether a valve has been abused or not, or should have somebody in

his service who could do this, and be able to remedy the trouble without annoying the manufacturer with it.

Following are a number of reasons why valves leak after being placed in a pipe line:—

1.—We are confident that 90 per cent. of all the trouble with leaky valves arises from the improper use of cement, and from the failure to remove the particles of cement, scale, chips, dirt, etc., that naturally get into the pipe while it is lying around a building, and lodge on the valve seat after steam is turned on. Cement should be applied on the male part only, for if placed on the female part it is apt to go through the pipe and get on the valve seat. In nearly all cases much more cement is used than is really necessary. If steam fitters would take pains to apply the cement as directed above, and would also make sure that the pipe is clean by standing it on end and striking it a few times with a hammer before putting it into place, in order to loosen any scale or dirt that may be inside, an immense amount of trouble would be avoided. As a further precaution, it is well, when a pipe line is first put into service, to open all the valves throughout the building, and blow steam through them thoroughly. After doing this properly there will be very little material in the pipes to cause trouble. When the line has been run for a short time, it would be well, as an additional precaution, to clean out all the valves thoroughly.

2.—It often happens that threads on pipe are cut longer, or smaller in diameter, than standard; and, when this is the case, the pipe, upon being screwed into the valve, is likely to run up against the partition and injure it.

3.—One of the common abuses is the application of a pipe wrench on the opposite end of the valve from

the end which is being screwed on the pipe. This should never be done, particularly with the lighter class of valves, as it is almost certain to spring the valve, and hence cause it to leak.

4.—If a light valve is put into a vise for the purpose of removing the centrepiece, the valve should certainly be clamped lengthwise. When removing the centrepiece care should be taken in all cases to have the disk some distance from the seat, as otherwise the disk will be forced down upon the seat, and some part of the valve will become strained. Never use an old, strained monkey wrench on a centrepiece, as a wrench of this sort is quite likely to squeeze the corners of the centrepiece out of shape. If it is found impossible to remove the bonnet or centrepiece by ordinary methods, heat the body of the valve just outside of the thread with a blow-torch, or any other available means that can be applied to the body and not to the centrepiece. Then tap lightly all around the thread with a soft hammer. This method never fails, as the heat expands the body, and breaks the joint made by the litharge or cement.

5.—When a stuffing box leaks, a steam fitter will often try to stop the leak by straining the stuffing box with a large wrench, when the real trouble is that the packing has become worn out and needs renewing.

6.—It sometimes happens that when a valve is to be used on a header, the steam fitter will start out with a long piece of pipe that is unsupported, and, through carelessness, will allow the strain due to the weight of the pipe to come on the valve, thereby springing it.

7.—In a pipe line where light valves are used, serious trouble is also likely to occur from the steam fitter not making proper allowance for expansion and contraction of the pipe system. The pipes and fittings are much more solid and rigid than

the lighter brass valves, and the expansion strains will, therefore, relieve themselves upon the valves, unless this action is prevented by allowing for the expansion strains in other ways. A good example of this is afforded by most of the high buildings that are heated by steam, where it is difficult to take care of the expansion. The steam fitter will branch out of his riser with a feed pipe to a radiator. The radiator usually stands close to the riser, and the branch feed pipe supplying it is run underneath the radiator to the end remote from the riser, where it is commonly connected to the radiator valve by a short nipple. The cross piece, or branch feed, under the radiator may be from 3 to 6 feet long, and is supposed to take up the expansion and contraction of the riser, which may amount to from half an inch to an inch and a half. The steam fitter does not appreciate the fact that the ordinary light angle radiator valve is the most flexible of all the connections, and will spring or distort itself before anything else in the branch. He makes his radiator valve serve as a swing joint and universal connection, and yet wonders why the valve leaks. In such buildings it is difficult to provide sufficiently for the expansion of the piping, and probably the safest way to ensure good work is to use valves of much heavier construction than usual, so that there will be no danger of their springing.

8.—Frequently, when a valve leaks, somebody will undertake to tighten it by using some kind of a lever on the wheel. This should never be done, as it will in all probability injure the valve. The trouble in such cases is usually due to the presence of dirt in the valve, and it is much better to take the valve apart and clean the seat than to try to force the dirt into the seat by the application of powerful leverage upon the stem.

Alcohol for Explosion Motors

Thos. L. White in "The Automobile"

IRON and aluminium are acted on by alcohol, whether pure or denatured, and these materials are, therefore, unsuited for the construction of tanks, carburetors, or other fuel receptacles, in which the metal surfaces are exposed over long periods to the action of alcohol. Possibly the difficulty can be met by electroplating the surfaces exposed to the alcohol.

Alcohol has certain advantages over gasoline in the matter of storage. If a can of gasoline be left open in the neighbourhood of a naked flame, it is liable to cause an explosion, owing to the diffusion of gasoline vapour into the surrounding air in sufficient quantity to form an inflammable mixture. This could never occur with alcohol. Then, again, water is useless to quench burning gasoline, serving only to spread the fire by floating the burning liquid. Thus we read every now and again of explosions in city sewers due to the waste gasoline from some garage floating on the surface of the sewage until the vapour from its evaporation becomes ignited. Alcohol can never be dangerous in such a case, for it mixes with water in all proportions, and in doing so becomes non-inflammable. In very hazardous cases, as in submarines, it is hardly doubtful that the superior safety of alcohol must eventually lead to its exclusive use.

In passing now to consider the properties of denatured alcohol in the carburetor and behind the piston of an explosion motor, it is not always possible to quote exact statistics, for the reason that the term "denatured" is far from definitive. For instance, if by denatured alcohol we mean a good standard French *alcool dénaturé*, containing 91 parts by weight of ethyl alcohol, 7 of methyl alcohol and 2 of acetone, we can assign a latent heat of 288 calories per kilogram. For pure alcohol this figure

would be 240, and for a denatured alcohol of unspecified composition any number intermediate between 240 and 288 might be the number required. There is here a considerable margin for error, and one which might lead to a serious miscalculation in estimating the minimum working temperature of the carburetor used to vapourize the alcohol in question.

There is one fact, which is true of all alcohol motors, whether the alcohol employed be pure, denatured, or enriched (*carburé*) by the presence of benzine, and that is that the exhaust gases invariably contain more or less acetic acid ($C_2H_4O_2$). If this compound be in excess, so that its characteristic smell is plainly noticeable, pitting of the exhaust valve seat and general erosion of the cylinder wall may be looked for. Happily this is rare, except in very badly constructed motors. In ordinary cases, to be safe it is only necessary after a run to inject a little oil into the hot cylinder and give the crankshaft a couple of turns. This protects the cylinder surface against the action of any acetic acid dissolved in water which may be precipitated as the motor cools.

The invariable presence of acetic acid as a combustion product has been attributed to various causes, but there is very little doubt, after the tests conducted by M. Sorel at Paris, in 1902, that it is not any original acidity of the alcohol used, but the formation of acid during combustion which is at the root of the trouble. Were it not so, we should expect the same alcohol used in a number of motors to produce a more or less uniform acidity in the exhaust gases. This is not the case. Then, again, the acidity is specially pronounced in the case of high-speed motors, where the time for carburation is short and where in consequence incomplete combustion is more likely to occur.

When the quantity of acetic acid passing through the exhaust is con-

siderable, sufficient, in fact, to cause erosion, it is generally accompanied by the deposit on the admission valve of a sticky incrustation. This phenomenon is due to the alcohol being partially atomized instead of completely vapourized. The small drops on meeting the hot metal are decomposed, their lighter constituents volatilize, and there is left a residuum which adheres.

Water-Tube Marine Boilers

W. L. Cathcart, in the "Technology Quarterly"

WATER-TUBE BOILERS for marine service may be divided generally into the "small-tube" and "large-tube" forms. The former class,—the "express" type,—is that used in torpedo craft and similar vessels where extreme speed for brief periods is the principal consideration, and hence where minimum weight and the ability to stand high forcing, without special regard to economy, are essential. These objects are attained by providing an excess amount of heating surface in thin tubes of small diameter, closely spaced and arranged for "accelerated" circulation; by carrying the least possible amount of contained water; and by making the casing and fittings relatively very light.

The "large-tube" boiler, on the other hand, is intended for general service in battleships, cruisers, and merchant steamers. Since such vessels must make long voyages in all weathers, and are at times far from a repair base, boilers for this service should have qualities of endurance in various respects which are not required from the "small-tube" type. Hence they have more contained water, are less sensitive in steaming, and are of stronger build and greater weight than "small-tube" boilers. "Large" tubes may be described generally as those of 2 inches in diameter and upward, although this

dimension is not wholly accurate for differentiating these two classes.

The following requirements should be considered in comparing water-tube boilers designed for general service at sea:—

1. Efficiency.—The boiler should have such combustion space, heating surface, water circulation, and baffling as will give it high efficiency at its usual rate of steaming, with, in war vessels, no serious reduction in that efficiency at the limit of reasonable forcing. This limit, under service conditions in the United States Navy, appears to be a consumption of about 40 pounds of coal per square foot of grate surface per hour.

2. Sustained Efficiency.—For sustained efficiency the tube system should be so arranged that both sides of the heating surface can be kept clean. Despite all precautions, some scale is sure to be deposited, owing to leaky condensers, defective valves, or an occasional unauthorized dose of salt feed when low water is feared. It is also impossible to keep the tubes entirely free from oil, since, although there may be no lubrication of the main cylinders, it will enter through the exhaust from dynamos, pumps, and other auxiliaries. Sediment may form also from oil and rust or the use of muddy water.

For these reasons the interior of the tubes should be readily accessible, both for inspection and the use of scaling cutters, while ample means should be provided for blowing the soot from their exterior while under way and for thoroughly cleaning the boiler when out of use.

3. Size of Units.—The boiler should be capable of construction in the form of single units of large power. A large number of small boilers means much added complication in piping, valves, fittings, and pumps, with a corresponding increase in the cost of maintenance and the care required in operation.

4. Sectional Construction.—Sectional construction of the tube system, i. e., the division of the heating surface into a number of similar elements, each (in action and fitting) independent of the others, is an advantage of much importance in obviating all strains due to unequal expansion and contraction and in making possible the erection of the boiler in sections on the vessel, thus avoiding all cutting of the decks in reboiling.

5. Weight.—Weight saving in both boiler and contained water is an inherent advantage of the water-tube system, as compared with the cylindrical type. This advantage should not, however, be pressed to extremes in boilers designed for general service at sea. It is false economy in such cases to limit the area and thickness of the heating surface, to build a light casing which will warp and leak, giving rise to large heat losses, and to have so small a volume of contained water that incessant vigilance is required to maintain its level in the gauge glass and to prevent the burning of tubes. The added weight required to give full combustion space, ample heating surface, a reasonable amount of contained water, and an adequate casing will, in service, be much more than offset by the reduction in the weight of coal required for long runs and in that of boilers temporarily disabled and carried as useless freight.

6. Repairs.—In warships frequently, and in all vessels at times, repairs must be made by the ship's force, unaided by the facilities of a repair base. Hence, so far as is possible, the boiler should be so designed as to enable this work to be done readily and quickly. The pressure parts should be accessible, simple, and uniform. Varied forms of tubes, unusual joints, and special fittings of any kind increase not only the difficulty of repairs, but the number of spare parts to be carried.

The Insulation of Insulators

From "The Electrical World"

COMMENCING with the green bottle glass telegraph insulator, of the size of a tea-cup, about ten years ago, the electric power-transmission engineers have been steadily increasing the size and cost of their high-tension insulators, until now they are using huge glass or porcelain insulators, the size of a cabbage. There has been no help for this visible swelling of the insulator. The little ones simply would not stand the electric stress, as the electric pressure rose by leaps and bounds. Even now the manufacturers would be ready to risk constructing transformers for 100 kilovolts if the line engineers would accept that pressure. Perhaps the line engineers may do so before long. The question is, What will their insulators then be? Will they be as large as umbrellas? Is long-distance transmission to be limited by the cost of conductors, or by the cost of insulators? A new suggestion is offered from Italy. Instead of placing the high-tension conductor on the top of the insulator, and arranging a series of porcelain petticoats beneath, so that a beetle would have to walk some 60 centimetres in the shortest path over the surface from wire to pin, the new insulator hangs the wire underneath the topmost petticoat which is expanded into a relatively thin umbrella. The purpose of the umbrella is only to shelter from rain and not to insulate, so that the umbrella can be made light and inexpensive. The actual insulator below the umbrella is stated to be considerably smaller than would be necessary if the umbrella were removed.

Steam Turbine Ships

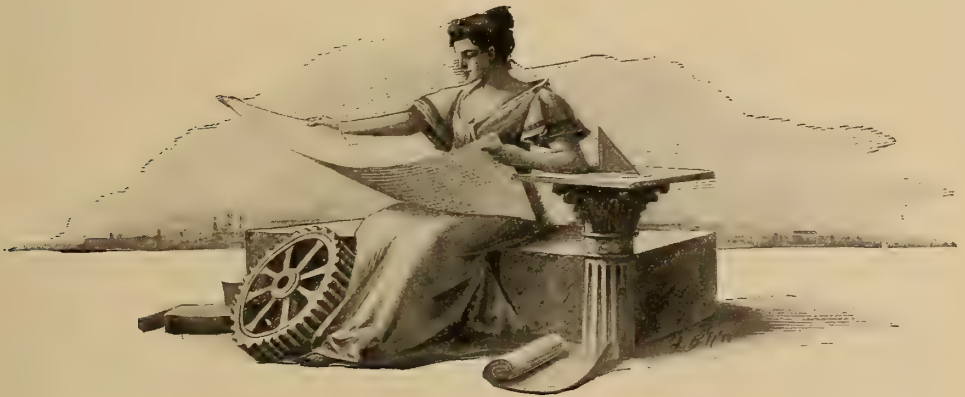
G. Gerald Stoney before the British Association

IT is only nine years since the little "Turbinia" was completed, and yet at the present time, out of a total number of 68 vessels on "Lloyd's Register" of over 20 knots, no less

than ten use Parsons turbines; whilst the largest steamers in the world, the "Mauretania" and the "Lusitania," which were designed to cross the Atlantic at 25 knots, and would require 70,000 horse-power, are being fitted with these turbines. The total horse-power of the marine turbines completed and on order approaches 1,000,000 horse-power. It has been found that cross-Channel boats with turbines use from 15 per cent. to 25 per cent. less coal than those with reciprocating engines, besides which there is a smaller engine-room staff, and a much less demand on oil, waste, and other stores.

All turbine vessels,—with the exception of the "Viper" and the "Cobra," which vessels had four shafts, and a yacht which had two,—have been fitted with engines of the three-shaft type, a high-pressure turbine on the centre shaft, and two low-pressure turbines on the wing shafts. The low-pressure turbines also contained the astern turbines, with the addition, in the case of warships,

of cruising turbines for low speeds. In very large ships four shafts are preferable, the high-pressure turbines being on the centre shafts and the low-pressure turbines on the wing shafts, but in small, slow-speed yachts two shafts have proved successful. In the case of tramp steamers of about 10 knots, a very great economy would be obtained by the use of an exhaust turbine with a reciprocating engine exhausting into it. An examination of the indicator diagrams of a tramp steamer would show that the steam was usefully expanded only down to about 7 pounds absolute, and that nearly the whole of the energy from 7 pounds to, say, 1 pound absolute, was wasted. By the use of the exhaust turbines the greater part of this waste heat could be recovered as energy, representing a net gain of 15 per cent. to 25 per cent. in the power, without additional fuel being burnt. It is expected soon to put this system into actual operation.



Current Topics

TO the power plant engineer who is trying to reduce his cost of production, even small savings in operating expense are worth while. In a steam-driven or a gas-engine plant the most attractive pos-

sibilities in reduced power cost lie in the mechanical department, and are closely related to the handling of the fuel. It is safe to say that in steam plants more attention is to-day being paid than ever before to boiler design,

methods of handling coal, manual and mechanical firing, load factors and superheating, and in gas-engine plants to reduced complication of equipment, more effective cleaning of the fuel, and lessened heat losses. The cost of power is often a small percentage of the total cost of manufacture of any commodity, and for this reason it is sometimes claimed that too much attention is being paid to the subject, in the face of greater losses occurring in other departments. The cost of selling an article may be too high, much greater in fact than the power expense in its manufacture. It is doubtless true that in any well-conducted business the wisest policy is to reduce the heavier items of expense first, but in actual practice it is not always an easy matter to do this. There is no reason why efforts should be neglected in the direction of lesser economies, in case the larger savings are difficult to make. The largest expense on a modern street railway, for example, is the cost of wages of motormen and conductors, inspectors, starters, etc. The labour expense may be 50 or 60 per cent. of the total cost of operation in this industry. Yet the saving of a small fraction of a penny in the power plant, or distributing cost per kilowatt-hour may mean a saving of the money value of several hundred thousand fares a year on a large system.

A COMMON defect in power-plant operation is the careless burning of electric lamps when not needed. Large stations require scores of incandescent lamps scattered about the premises, and it costs money to operate these. By controlling the lights from one central point as far as possible, and inserting a red-coloured lamp in each circuit at the switch bank, a material saving has often been effected through the moral effect of the red lamp. Again,

the re-location of the voltmeter and rheostat handle in the boiler room in a "one-man" plant resulted in much better regulation than previously existed. It is sometimes possible to cut out large transformers from a bank of units when the load is light, and thus reduce core losses. Many of these methods of saving power-plant leaks are overlooked by engineers because of their very familiarity.

ONE of the most interesting developments in the field of urban transportation at the present time is the growing favour with which subways are regarded by the public everywhere. All the recently built underground railways have been handling an enormous traffic, almost from the first days of their operation, and in the case of the city of Boston the subway habit has outgrown the bounds of the city proper and fastened itself upon the adjoining suburb of Cambridge. The latter represents probably the first instance of an important subway being authorized for immediate construction in a suburban community. It is an open question how much farther the building of elevated railways will be pushed in large cities in view of this subway tendency. At this time an extension of the Boston elevated system about $2\frac{1}{2}$ miles in length is under active construction, but the public demand for subways is so insistent at present that it is uncertain which type of line will be more widely used in the future. Enormous land damages accrue from the erection of an elevated structure in a street, and there can be no doubt that the appearance of a public thoroughfare is not improved by the building of an elevated line upon it. Still it is pleasant to travel in the sunlight and air of an elevated line, as compared with a subway route.

IN either case the construction cost is very high. The distances of rapid transit routes in cities are relatively short, so that underground travel does not present the monotony which an interurban subway trip of many miles would thrust upon the passengers. The submarine tunnel for electric cars is independent of draw-bridge troubles and weather conditions in general. Bearing in mind the decreased noise of operation and absence of offensive street obstruction, it is probable that subway or tunnel routes will be favoured more and more as the years pass; the present elevated systems will doubtless continue to give good service for a long time to come, but if present indications are any criterion, the subway is destined to be the winner in the long run.

THE increasing use of electric hoists in the construction of buildings of all kinds indicates that building contractors are growing more and more alive to the peculiar advantages of this class of equipment, and also illustrates how constantly engineering progress is working for the betterment of the conditions of living in cities. It is possible that within a few years the steam hoisting engine will be very largely superseded by the electric motor in the congested districts of great cities of population. The field of the steam-driven hoist will in such an event be confined principally to locations where a flexible supply of electric power is not available at reasonable rates. In many cities the introduction of electric hoists has been extremely slow for one or more of the following reasons:—Contractors have already in commission a large investment in donkey engines, and consequently dislike to invest in other equipment; the cost of electric power for hoisting work is often high, and the facilities for actually getting power from the central station mains at the right voltage or of the proper

kind of current are very frequently poor. Under such conditions it is difficult to arouse much enthusiasm on the part of the intensely practical contractor. In fact, much depends upon the progressiveness and initiative of the local central station company.

THERE is really no good reason why half-a-dozen different voltages should be needed by hoisting motors for service in the business districts of large cities, any more than that the boilers of donkey engines operating in the same section of the city should be operated at five or six widely different steam pressures. In a well-designed distribution system, electric power at some uniform voltage should be generally available throughout the area of economical supply. Provision for temporary connections between the site of the contractor's work and the distribution circuits should not be difficult to make if the circuits are of the overhead type, and even if the lines are run in underground conduits it ought to be a simple matter to make a service connection from some adjoining service branch, outside the meter. Power leads might be brought up through arc light poles in the various blocks and dead-ended in pot heads to await temporary use.

WHEN the electric hoist is used in building construction, it eliminates the dirt, smoke, and steam inseparable from the use of the donkey engine; it obviates the delays which arise through the stoking of the boiler, and through the obscuration of the view of derrick workers and attendant; it avoids the frightening of timid horses; and it does away with all danger of explosions. When operated intelligently, it is much less noisy than the steam hoist, and can be run at night with far less objection from surrounding property own-

ers; it also allows the attendant to devote all his time to the actual work of hoisting and lowering. After only half a day's first use of an electric hoist, an engineer who had operated a donkey engine for about fifteen years expressed himself recently as preferring the motor-driven machine to the steam-driven outfit. The hoisting load is, of course, temporary; but it amounts to a considerable integrated power demand in the erection of a large building, and deserves very reasonable rates when sold on a daylight use basis.

IT is rightly a source of satisfaction to all friends of permanent progress that broader conceptions of engineering are becoming more and more prevalent, both among laymen and professional experts. The influence of the engineer is felt to-day in civilized communities as never before, and the vast material progress of the western nations in the past hundred years has brought home to the average man the certain truth that the engineer is, in a broad sense, a cosmopolitan worker for the good of humanity. The whole world is his field, and never again is the true engineer likely to be regarded by intelligent men as a narrow-minded, provincial dealer in materials and natural laws, unable to comprehend the broad relations of his special knowledge and the world's needs, or to appreciate the proportions of an industrial problem in which he plays but a fractional part. Within the engineering profession the financial bearing of problems is coming more and more to the front; the relation of man to man as expressed in industrial betterment work, a wider interest in labour as a factor in production and construction economy, and campaigns against waste are being studied, with a view toward securing lasting progress away from limited and selfish conceptions of large affairs. Science and economics are

closer together to-day than for any time with which we are familiar, and the outlook for the future of engineering, based on the tendencies of the present time, is both stimulating and satisfying.

TO the steam engineer the fuel economizer,—indeed, to be more specific, the Green fuel economizer, for that seems to have been the first of its kind—is one of the elements of good modern practice. In this alone there is sufficient reason for the portrait this month of Sir Edward Green, Bart., to whom the profession is indebted for the development in great part of the apparatus bearing his name, though the idea of the apparatus was conceived by his father, the late Mr. Edward Green, of Wakefield, England, who died in the early sixties of last century. Since the construction of the original economizer, improvements in form and in other details have been made, but in principle the apparatus is much the same now that it was in the days of the elder Mr. Green. During the intervening years the establishment at Wakefield of Messrs. E. Green & Sons, Ltd., has doubled and quadrupled in extent, and years ago also the industry was transplanted in part to America, where, at Matteawan, New York, the Green Fuel Economizer Company eventually succeeded Messrs. Green & Son, Mr. Frank Green, a son of Sir Edward, becoming the president of this later company. Sir Edward was created a baronet during one of Lord Salisbury's administrations. In private life the genial baronet has hosts of friends, and at his country home or in London Sir Edward's name stands for the best traditions of old-fashioned hospitality. Since the death of Lady Green he has resided at York, a convenient center for his own business and the meetings of the Lancashire & Yorkshire Railway, of which he is a director and in whose prosperity he takes much interest.



PHOTO BY LAFAYETTE, LONDON

CALVIN WINSOR RICE

THE NEW SECRETARY OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

SEE PAGE 173

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LIFTING MAGNETS

By Arthur C. Eastwood

THE electro-magnet dates back to 1820, when Oersted discovered that the neighbourhood of a conductor conveying an electric current possesses magnetic properties. This discovery was followed by the experiments and deductions of Sturgeon, Henry, Joule, and others, and later by the mathematical researches of Maxwell, Hopkinson, Ewing, and other scientific investigators.

The properties of the electro-magnet with which we are here concerned consist in the ability of the magnet to attract and hold particles of iron and steel when an electric current is passed through the magnetizing winding and to release the attached load when the flow of electric current is interrupted. These properties of the electro-magnet were early discovered, and, since 1825 at least, have formed the subject of many interesting and instructive laboratory experiments, and of many useful practical applications as well. Among the latter may be mentioned the electro-magnetic telegraph, the earlier forms of electric motors, and, with slight modifications, the telephone receiver and the modern electric motor. In all of these cases the electro-magnet acts invariably upon



FIG. 1.—A LIFTING MAGNET HANDLING WIRE SCRAP
AT THE NEWBURG STEEL WORKS, NEWBURG, OHIO



FIG. 2.—HANDLING ARMOUR PLATE WITH LIFTING MAGNETS MADE BY THE ELECTRIC CONTROLLER AND SUPPLY COMPANY, CLEVELAND, OHIO, U. S. A.

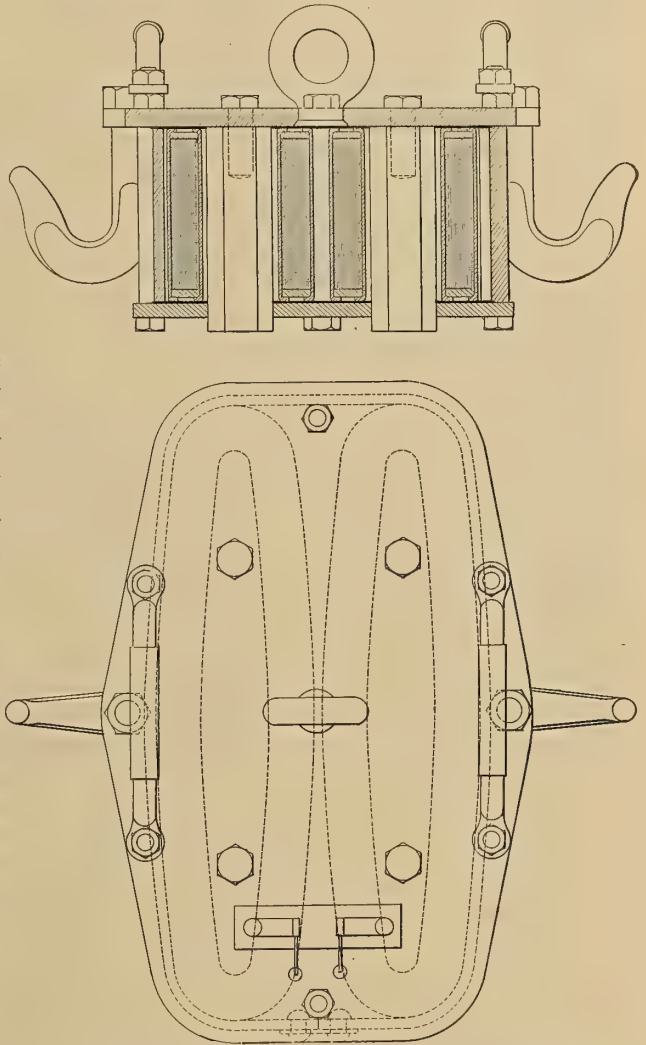
a given armature. In the lifting magnet, however, while the same magnetic properties are made use of, the armature to be attached and held by the magnet is variable, consisting of the load to be lifted, and this constitutes a very essential difference between the lifting magnet and other forms of electro-magnets, as will be presently seen.

Mr. S. T. Wellman, a pioneer in the manufacture of open-hearth steel in America, was one of the first to grasp the possibilities of the electro-magnet as a ready means of attracting and holding iron and steel products while being lifted and transported by cranes and similar labour-saving machines.

The lifting of long, thin steel plates by means of slings and hooks had always proved a tedious and difficult matter. The plates had to be pried up in order that the hoisting tackle could be attached, or spacing blocks must be left between the plates when piled horizontally. When the plates were of considerable length and width a great deal of head-room was required, owing to the necessary spread of the hoisting chains, and accidents were frequent, due to slipping of the hooks commonly used for grasping the plate.

To Mr. Wellman's mind, the electro-magnet offered an ideal remedy for these difficulties. What could be more ideal than to attach an electro-

magnet to the hoisting tackle of the crane, lower the magnet upon the plate to be lifted, grasp it by the simple closure of an electric switch, convey it to the desired spot and



FIGS. 3 AND 4.—VERTICAL SECTION AND PLAN OF THE FIRST DISTINCTIVE LIFTING MAGNET, DESIGNED BY S. T. WELLMAN, IN 1895.

release it by simply opening the switch?

The idea was so enticing that Mr. Wellman at once set about putting it into execution. The first magnet was built by a prominent manufacturer of electrical apparatus. When put in service, it lasted just long

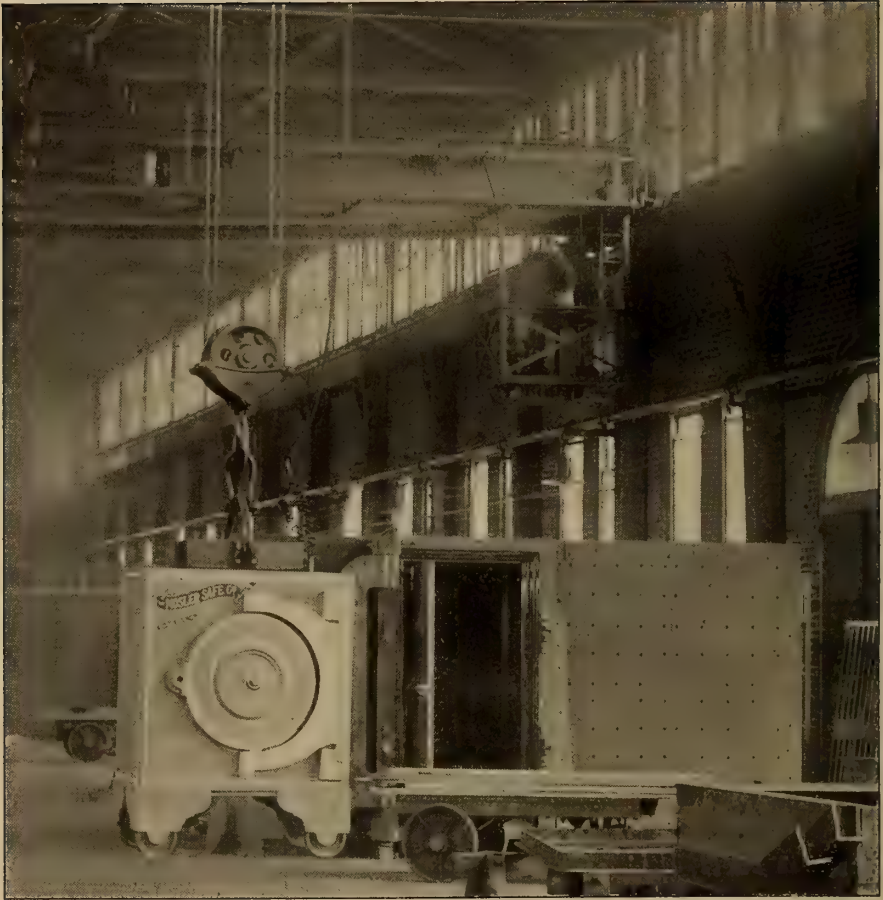


FIG. 5.—LIFTING MAGNETS RAISING A SAFE AT THE WORKS OF THE MOSLER SAFE CO., HAMILTON, OHIO

enough to demonstrate the possibilities of the lifting magnet. Although built by manufacturers accustomed to the design and construction of electro-magnets used in dynamos and motors, the magnetizing coils burned out so rapidly as to condemn it as a practical piece of apparatus. An electro-magnet dangling at the end of a hoisting chain, exposed to the weather, abrasion and rough handling, and, above all, subjected to the inductive discharge at high voltage which occurred each time the magnetizing circuit was opened to release the load, constituted a new article of manufacture which required special design. Mr. Wellman then undertook the design of an electro-

magnet, which, as far as shown by the records of the United States Patent Office, was the first distinctive "lifting magnet." See Figs. 3 and 4.

In his design, Mr. Wellman provided means for entirely enclosing and protecting the magnetizing windings, a practice followed in all subsequent successful lifting magnets. Many magnets built in the early nineties in accordance with the original Wellman design are still doing good service.

The design of lifting magnets was later still further advanced by Mr. Eugene B. Clark, of the Illinois Steel Company. A typical magnet of the Clark type is shown in section in Fig. 6. This magnet is par-

ticularly adapted to lifting plates from a horizontal position and raising them edgewise so that they may be stored in vertical racks. The same type of magnet is used in shipyards for lifting steel plates from the ground and holding them while being attached to the vertical sides of ships.

Fig. 2 illustrates a set of such magnets built by the Electric Controller & Supply Company, of Cleveland, Ohio, for the Imperial Shipyards of Yokohama, Japan.

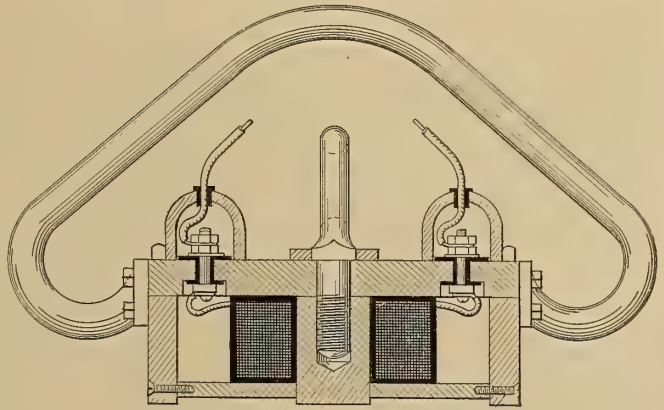


FIG. 6.—A CLARK LIFTING MAGNET

ing the switch which controls the magnet. As the magnetic flux dies out, the lowermost plate drops first, and if the switch be then closed, the



FIG. 7.—HANDLING PLATES AT THE SOUTH WORKS, AT SOUTH CHICAGO, OF THE ILLINOIS STEEL COMPANY

In the handling of plates, a number of them may be lifted at one time and dropped one at a time in a manner so simple as to seem almost absurd. This is accomplished by simply opening and clos-

remaining plates will be held by the magnet. The crane operator becomes familiar with the time element of the magnet after a few trials and can readily pick up half a dozen plates at one lift and distribute them, one

at a time, in various cars or piles as desired.

At first thought, it seems that the design of lifting magnets for handling smooth, homogeneous magnetic material, such as plates, slabs, blooms, etc., should prove a very simple matter, involving nothing more than a consideration of elementary and well-understood laws of the magnetic circuit. This has not been found to be the case; and, in fact, it is probable that there is no other type of electrical apparatus which has so persistently defied the theoretical figures of the designer when reduced to practice. The magnetic circuit of the magnet proper can, of course, be made the subject of more or less exact calculation, but this circuit is normally incomplete, and the resulting magnetization depends upon the charac-

ter of the armature,—in other words, upon the load to be lifted.

A magnet which will lift a steel ingot weighing 5000 pounds may not lift a long, thin plate weighing 500 pounds,—the armature is not only magnetically, but mechanically different. The thin plate, in addition to its small magnetic cross-section, is very flexible, and the parts of the plate which overhang the poles of the magnet introduce a bending moment tending to tear the plate from the poles of the magnet. In addition to this, when the plate is lifted, it will be set in vibration by the motion of the hoisting tackle, and this introduces a live load which must be taken care of by the magnet. The air-gap between the poles of the magnet and the load to be lifted (which depends on the smoothness of the surfaces, the presence or absence of scale, dust, snow, ice, etc.) is also an important factor, affecting both the total magnetic flux and its distribution. It may be noted also that available text-books on the subject of electro-magnets contain only a very meagre amount of reliable data relating to the traction of such magnets.

It must be evident, then, that the design of lifting magnets not only necessitates familiarity with the laws of the magnetic circuit, but also a thorough understanding of the conditions to be met and the ability to properly interpret these conditions in the design. This ability can be attained only by experiment and practical experience. Much of the success attained in the later designs of such magnets is due to persistent experiment and the gaining of experience under operating conditions extending over a period of nearly ten years.

The Electric Controller & Supply Company, for example, at the outset constructed a testing machine with a capacity of 15,000 pounds for the purpose of obtaining experimental data. Since that time each magnet constructed has been tested under



FIG. 8.—LIFTING SEVEN KEGS OF NAILS

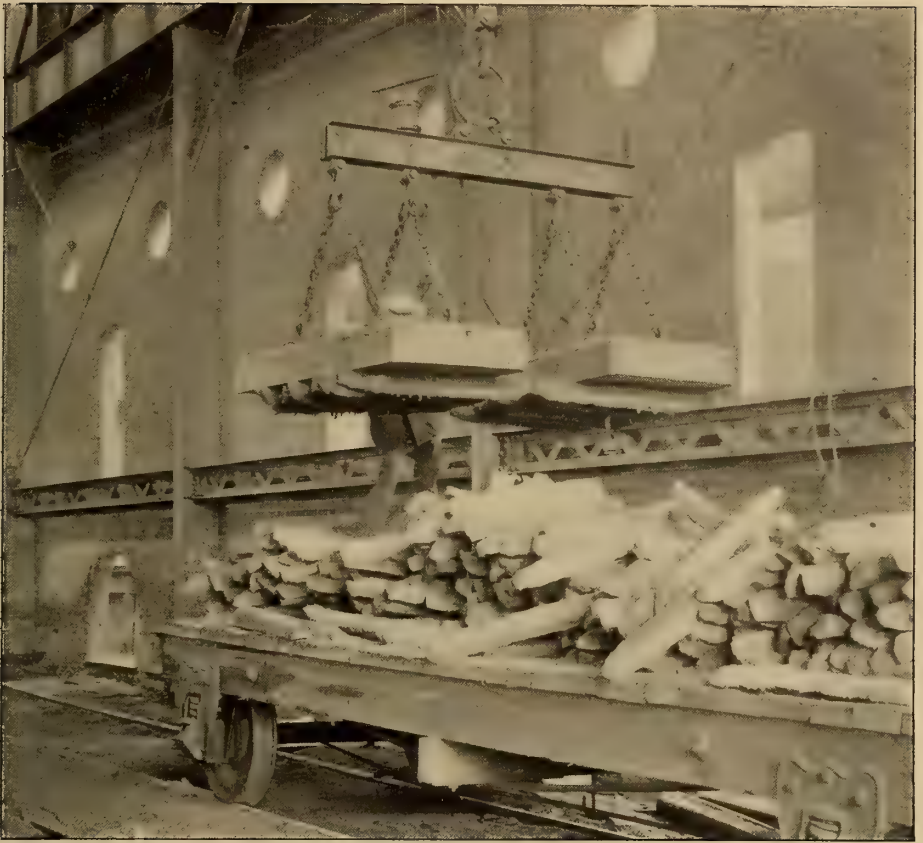


FIG. 9.—HANDLING PIG IRON HOT FROM THE SAND IN THE CAST HOUSE OF THE BUFFALO UNION FURNACE OF THE M. A. HANNA CO. AT BUFFALO, NEW YORK

prescribed conditions, and its operation in actual service has been carefully followed. In view of the large number of magnets which have been built and tested in this way, abundant data have been secured for correlating theory and practice.

So far we have dealt only with magnets for handling what may be termed homogeneous magnetic material, such as plates, slabs, etc. Other problems remained to be solved in handling what may be termed "detached" material, such as scrap, pig-iron, and the like. Until only a very few years ago it was considered quite out of the question to lift pig-iron economically by means of a magnet. A lifting magnet which would readily lift an ingot weighing

10,000 pounds would not lift a single pig weighing 100 pounds when lowered upon a pile of pig-iron.

Pig-iron, of course, possesses poor magnetic properties, owing to the impurities which it contains and to its more or less open physical structure. A pile of pigs presents an uneven surface, with large air-gaps between adjacent pigs. Necessarily these conditions demanded a much greater magnetizing force than that required for lifting a steel ingot. The provision of what appeared to be the requisite amount of magnetizing force did not, however, produce the desired effect. The magnetic lines seemed to wander more or less aimlessly through the pile of iron in such scattered fashion that there was



FIG. 10.—A MAGNET LIFTING SOW AND PIGS FROM THE SAND IN A BLAST FURNACE CAST HOUSE



FIG. 11.—LIFTING RAIL ENDS 2 BY 4 FEET LONG

not a sufficient flux-density to produce the desired lift, and, owing to the unevenness of the surface of the pile, only a small portion of the pole area of the magnet secured contact with the metal to be lifted.

An attempt was made to overcome these difficulties by providing the magnet with movable pole pieces which would adjust themselves more or less to the irregular surface of the pile. A magnet of this character, designed by S. Piek, is shown in Fig. 13. As actually constructed, the Piek magnet was provided with seven central and twelve outer pole-pieces, which were loosely held in pockets in the central and outer poles of the magnet in such manner as to adjust themselves vertically to the load to be lifted. The idea appeared to be a good one, but the

performance of the magnet, when actually constructed, was very disappointing. With a magnet weighing between eight and nine thousand pounds and requiring 50 amperes of current at 220 volts, only from six to eight pigs could be lifted from a miscellaneous pile. Excessive magnetic leakage, due to the long pole-pieces, appeared to counteract any advantage to be gained by adjustability; in fact, the pole pieces were gradually shortened, and better results were finally obtained by altogether discarding the outer adjustable poles.

The problem of designing a magnet for lifting pig-iron and other detached material was attacked by the writer in a radically different manner, and resulted in a magnet in which the central pole, instead of



FIG. 12.—LIFTING RAILS WITH A MAGNET MADE BY THE ELECTRICAL COMPANY, LTD., LONDON

being adjustable toward the load to be lifted, was apparently carried away from the load. As shown in Fig. 16, the central pole face is located well above the outer annular pole. The design appears paradoxical, and, in-

deed, has been called idiotic. The performance of the magnet, however, has fully demonstrated the correctness of the principles upon which the design was based. A magnet of this type, weighing approximately 5000

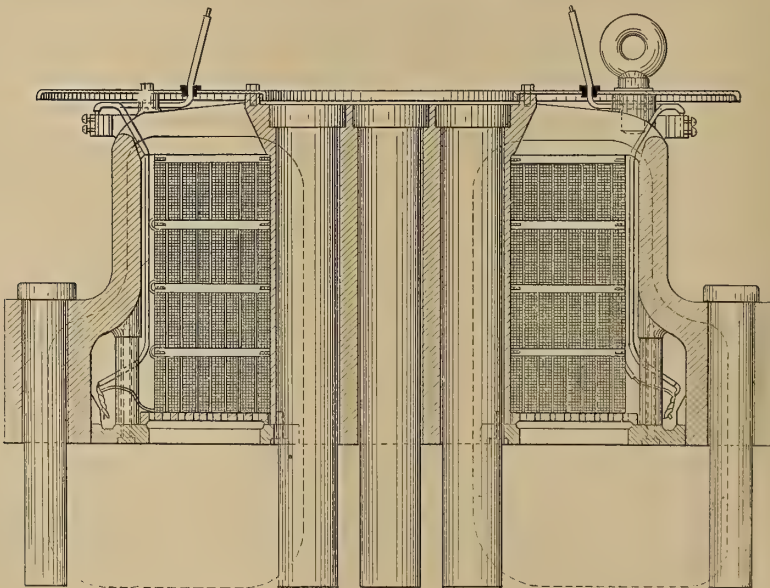


FIG. 13.—A PIEK MAGNET WITH MOVABLE POLE PIECES



FIG. 14.—A LOAD OF MACHINE-CAST PIG IRON

pounds and requiring 27 amperes at 220 volts for full excitation, will lift from twenty to twenty-five pigs from an indiscriminate pile. Its performance in lifting other forms of detached iron and steel products may be judged from some of the photographic reproductions printed in these pages.

The primary idea underlying the design of this magnet was to produce such a dense and well-directed magnetic flux that the material to be lifted would rise to meet the poles of the magnet. In actual service an 80-pound pig of iron will jump vertically from 4 to 6 inches to attach itself to the centre pole. The load which is lifted forms not only the armature of the magnet, but a portion of the core as well. A greater weight of detached material is, there-

fore, required to satisfy the magnetic circuit than would be the case if the load formed merely the armature, so that the lifting capacity of the magnet is correspondingly increased.

In a magnet which is to handle from 300 to 800 tons of iron per day, it is evident that the design of the magnetic circuit is not the only thing to be considered. It is doubtful whether any other piece of electrical apparatus is called upon to operate under such extremely severe conditions. As previously mentioned, in the case of the magnet shown in Fig. 16, pigs of iron will jump several inches to attach themselves to the magnet. Only the very staunchest construction can withstand the daily hammering of 800 tons of such pigs, and, in addition to this, in rapid working, the magnet itself is fre-



FIG. 15.—LIFTING A 12,000-LB. SKULL CRACKER
WITH A MAGNET

quently lowered with considerable force upon the material to be lifted. The methods of insulating the magnetized winding, holding it in place,

providing for its expansion, and protecting it from moisture and from vibration, all require the most careful study and design; likewise, the effects of abrasion on the active face of the magnet must be provided for.

Now that these problems have all been successfully solved and the lifting magnet has been reduced to a practical and dependable device, it is being very rapidly adopted by manufacturers and users of iron and steel products, with the introduction of great savings in the cost of handling such materials.

In addition to the actual reductions in labour cost which may be effected by the use of lifting magnets, many indirect savings frequently result from their installation. For instance, on account of the increased speed at which material can be handled by a magnet, it frequently occurs that the installation of a magnet on a crane will permit of an increase of the plant and a corresponding increase in the amount of material to be handled without addition to the crane facilities.

With a crane and magnet, material can be economically piled to a height which would be out of the question where hand-labour is employed. hence, where only a restricted area is available for storing material, the value of this area may be largely increased by installing a magnet.

A further labour-saving and novel application of lifting magnets consists in their use in connection with "skull-crackers" for breaking up "skulls" (the metal which clings to

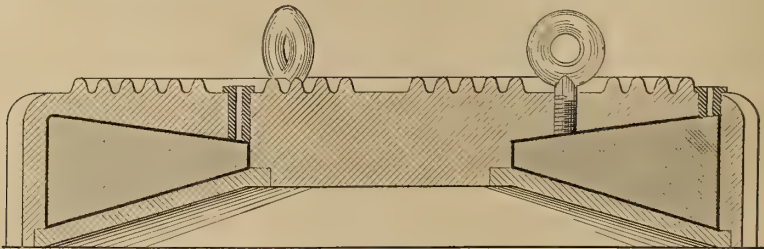


FIG. 16.—THE EASTWOOD IMPROVED LIFTING MAGNET



FIG. 17.—MAGNET DROPPING A SKULL CRACKER BALL

the lining of hot-metal ladles), imperfect castings, etc., which must be broken before it is possible to charge them into a furnace for remelting. This process was formerly performed by a mechanically operated "drop," consisting of a suitable crane or other hoisting device to which could be attached a drop-weight by means of a suitable latch. When the weight was raised to the desired height, the latch was tripped by means of a rope and the weight dropped upon the material to be broken.

The castings to be broken were usually dragged into position by the use of slings or chains. The drop-

weight had a disagreeable habit of almost invariably glancing to one side in such a position that the latch could not again be attached without righting the ball, and the prying up of a more or less spherical ball, weighing from ten to twenty thousand pounds, requires much labour. The broken castings were usually gathered up and loaded into suitable cars or receptacles by hand. A number of labourers were required, and accidents from flying pieces of broken castings were frequent.

By the use of a lifting magnet all of this is altered. The castings to be broken are placed in position by the crane and magnet. A spherical

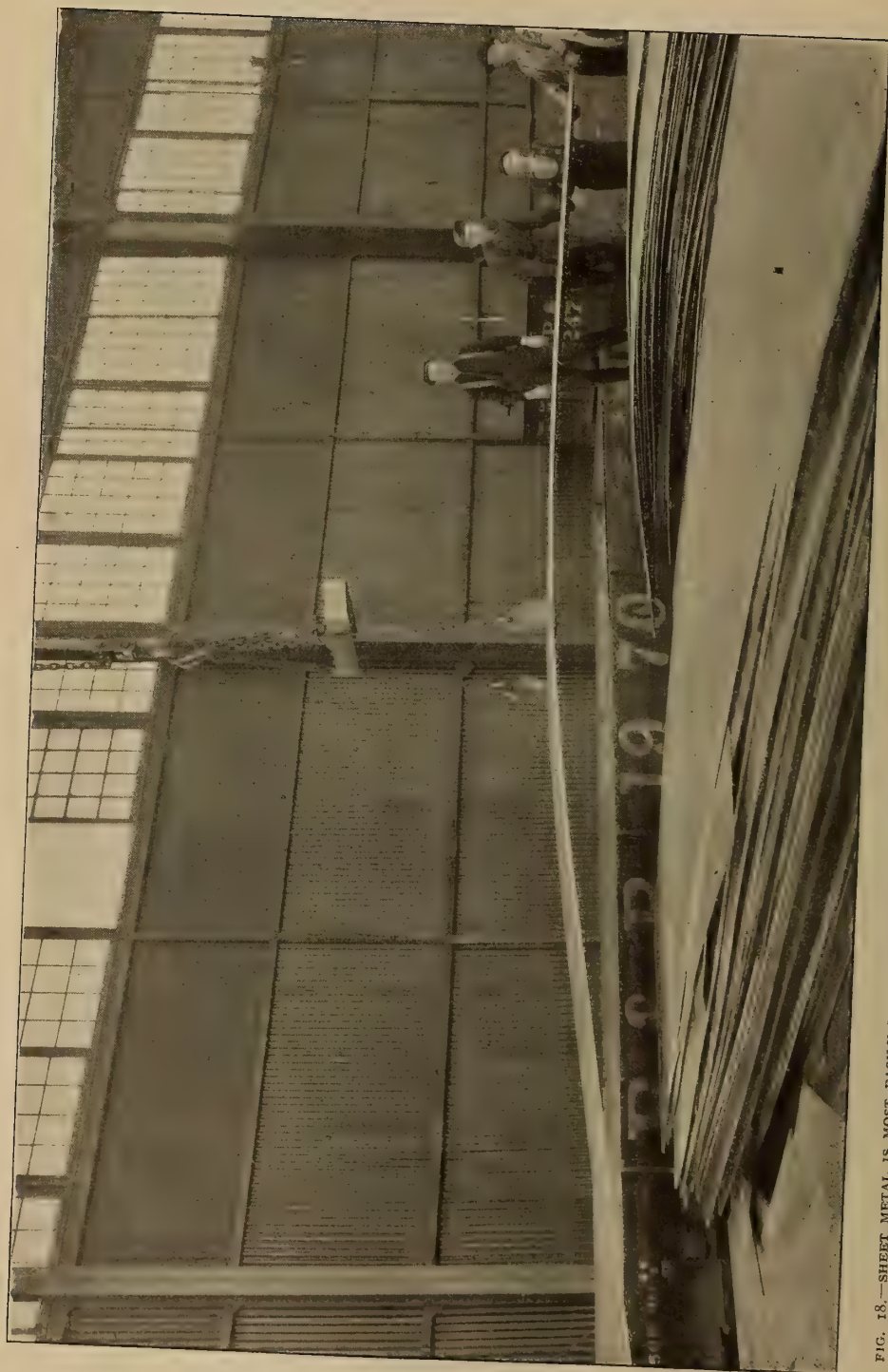


FIG. 18.—SHEET METAL IS MOST EASILY LIFTED OFF THE PILE WHEN A MAGNET IS USED. AFTERWARDS THE HOOKS ARE PLACED UNDER THE EDGES OF THE PLATE AND THE MAGNET IS RELEASED. MADE BY THE ELECTRIC CONTROLLER & SUPPLY CO., CLEVELAND, OHIO, U. S. A.



FIG. 10.—MAGNET UNLOADING SCRAP AND PUNCHINGS FROM CARS TO STACK PILED IN THE YARD OF THE LAKE ERIE IRON COMPANY, CLEVELAND, OHIO

drop-ball is employed, which is engaged by simply lowering the magnet upon it and closing a switch. When hoisted to a suitable height, the weight is released by opening the switch. The broken pieces of the "skulls" or castings are gathered up by the magnet and loaded into charging boxes. There is ordinarily no need of ground labour, the entire operation being conducted by the crane operator. By the use of a magnet, not only is the process of breaking castings greatly facilitated and cheapened, but the risk of accident is largely eliminated.

A few words as to the safety of handling material by means of magnets may not be amiss. Accidents due to the slipping and breaking of hooks, tongs and slings, which are commonly used for attaching loads to the hoisting tackle of cranes, are known to be of frequent occurrence. As a general proposition, if a lifting magnet is designed with a proper factor of safety, and if reasonable precaution is taken in installing the wiring supplying current to the mag-

net, there will be less danger of accident than is the case with any of the commonly used devices for attaching the load to the crane hook. This is particularly true in handling bulk material, such as pig-iron, for, aside from the relative safety of the magnet, by its use the presence of labour on the ground is largely dispensed with.

The only serious risk of dropping the load carried by a well-designed magnet lies in the opening of the circuit. If the magnet is fed from a separate circuit carried ahead of the circuit-breakers to the terminals of the generator, nothing short of the shutting down of the power plant or the breaking of the line supplying the magnet can deprive it of current,—contingencies which, in a well-organized plant, are more remote than the slipping of hooks and cranes.

In practice, the modern lifting magnet has proved a safe and dependable apparatus, with great labour-saving possibilities, and its more general use seems assured.

MODERN FACTORY MANAGEMENT

By Egbert P. Watson

MODERN factories of all kinds have changed so much in the last half century that those who are familiar with the old order of things cannot but wonder how the changes in every direction can be made profitable. The outlay for everything, from the foundation to roof, is so extraordinary that it does not seem possible to earn dividends large enough to satisfy stockholders with their investment. The founders of modern workshops have, apparently, sought opportunities to spend money lavishly for what seem to be superfluities that add nothing to the working plant or its efficiency, but are supposed in some way to assuage the pangs of those who are compelled to work for their daily bread.

In the course of a long life spent among workmen of all callings, craftsmen from all parts of the world, of high and low degree, it has never occurred to me that they were desirous of anything more than ordinarily decent surroundings and conveniences to enable them to earn their bread, or that they appreciated or even understood the motives of those who sought to improve facilities so that they would not have to exert so much more muscular effort to get through the day, this last being looked upon as a device to get more out of them.

Their argument is that they are in the shop to do a day's work, whether this be much or little; anything that tends to hurry the job along shortens their time of holding it, and they feel that all the time-saving goes into the boss' pockets, and comes out of theirs, so that they are not enthusiastic on the subject of improvements of any kind.

Systems, so called, whereby the work is "routed" from start to finish, are particularly distasteful to them, none more so than the constant supervision, and, as they feel it, espionage, that prevails everywhere as part of the route system under which each detail is supposed to occupy just so much time. Observation and experience have convinced me that, as a rule, men are managed too much, and that the average man is anxious to give a "fair day's work for a fair day's pay."

The methods employed to control large bodies of men vary with the nature of the work to be done, but the chief factors leading to successful administration are a good knowledge of human nature, tact, and a thorough personal knowledge on the part of the overseers of every detail of the undertaking. Those who have such qualifications will succeed where others who lack them will have trouble nearly all the time because they are only tolerated by the help instead of being heartily seconded and confided in throughout the working day, and even outside of it in the intimate concerns of home life.

A striking instance of this last was witnessed by myself years ago at the shops of the Pratt & Whitney Company, at Hartford, Conn. This concern was established nearly half a century ago by Francis A. Pratt and Amos Whitney, and has been in continuous operation ever since. I do not think that there ever have been any labour troubles there of any kind, certainly none that I have ever heard of, and for the first thirty-five years of the life of the

shops I was in and out constantly, having, as one may say, the "run" of the establishment in all parts. I was at the time connected with a steel works doing business with the Pratt & Whitney Company, and was thus in a position to see many things that others could not see. On one occasion Mr. Pratt and I were in the office talking over the sale of a considerable quantity of steel, when a little girl passed the window with a basket on her arm. Mr. Pratt at once jumped up, ran to the door and called the child back.

"How's your father getting along?" he asked when she arrived. "Tell him not to worry, his job will be kept for him, and we will take care of the doctor's bill, too; we can't get along without him," and sent the little girl away with a joyous face.

Returning, he said to me:—"Her father got hurt last week in the foundry through no fault of his own, crane broke down," and that was the sole allusion he made to the matter. It was not done for effect; Mr. Pratt was the last man to pose, certainly not before a steel salesman. It was characteristic of the man, but the incident was not lost on me, and I said to myself that there were not many presidents of large works who would even know that a foundry labourer had met with an accident in the course of his work through no fault of his own, much less recognizing one of his children passing the shop, and drop his conversation with an agent to go out and say a kind word to her.

But, as remarked, this was characteristic of Mr. Pratt; he said on one occasion that he knew every man in the shop who had been with them for any length of time, which was quite probable, seeing that he was among them at all times of the day, distributing praise or blame with an impartial mind, "Good for you, John," when a good job appealed to him, or the reverse, on occasion, for Mr. Pratt was prone to spontaneous combustion under great pro-

vocation, "like the flint, which being much enforced doth show a hasty spark and straight is cold again." But there was never any doubt in the delinquent's mind as to Mr. Pratt's views on the subject of poor jobs. No one was ever summoned to his private office to be lectured but the verbal "axe was laid to the root of the tree," and that was the end of the matter. He was equally outspoken to customers who were not up to date with their plans and made more trouble and delay in the shop than their trade was worth.

Once in the draughting room a young man approached us and asked Mr. Pratt when his machine would be ready for delivery.

"I'll tell you," was the reply, "it will never be ready, for the simple reason that you don't know what you are trying to do. Take it somewhere else; we are tired of it and won't be bothered with it any longer."

That ended the interview, for Mr. Pratt walked off, saying, "That fellow has been fussing with a patent pulley-clutch for the last six months and is no nearer a solution of his troubles than when he began, for it won't work yet; I don't know how many times we have pulled it down and set it up again, and we haven't time to experiment for people who don't know their business. We could make it work all right in a few hours, but that is not a part of our business, to cobble up patented articles."

The young man had intimated that part of the failure of his plans was due to bad workmanship. Mr. Pratt did not reply to this on the spot, but said to me:—

"Come out here; I want to show you something," and in another part of the shop he introduced me to an automatic grain weigher in bulk, merely a large hopper, holding, possibly, two barrels of wheat, with a little mechanism below it. Mr. Pratt pulled a slide in the bottom of the

hopper, started the machine, and grain ran into a scale pan; when this was full it tipped to one side and discharged the grain into a bag beneath. When the hopper was nearly empty Mr. Pratt said to me:—

"Take three grains out of the scale pan."

I did so, and the machine stopped and would not tip the pan until the three grains had been returned to it. When the hopper was nearly empty, a bell rang to call attention to the fact.

"I think that is pretty good workmanship for a machine shop, don't you?" said Mr. Pratt. "It will weigh as accurately as an apothecary's scale and go on continuously with the rough-and-tumble attention it will get in a flour mill."

As this paper is not written to exploit the Pratt & Whitney shops, I will not allude further to them, and have mentioned them only as an instance of my belief that managers are born, not made, simply because there never will be any codified list of rules for the handling of men that will cover every exigency that may arise. So much depends upon natural tact and accurate knowledge of human nature, what to see and what not to see, that it is not given to all to distinguish themselves as managers.

The foregoing illustrates one phase of shop administration which proved successful in the hands of certain men, but there is another which is also working well in an establishment making a staple article with a force of several thousand men, women, and children of all ages and nationalities. The system covers both day's work and piece-work; where the wages depend wholly upon the manual dexterity of the operator; but this may be called a distinction without any difference, for in both cases a fixed output of the machines or the hand workers is expected, even demanded, and those who do not come up to the requirements are not retained, but dropped sum-

marily from the rolls without an interview. Their pay envelope is red, blue, or green, as the case may be, when there is no more work for them, and that is the court of last resort; the work incident is closed. In the economy of the works a fixed output is needed year in, year out, and the machines will supply it if properly attended; otherwise, they are readjusted until they do.

The loss of parts through the fault of machines falls upon the shop, but when the operator's work, by his negligence, does not pass inspection, he is compelled to make it good in his own time, or in some cases is put upon day wages until the full count of parts has been made up. By this last plan the operator does not lose all of his time, but if he proves habitually careless, he is dropped from the roster permanently.

The new methods of shop administration overlap the old, and there are still many managers who cannot see the advantages claimed for the combined athletic club and restaurant, to say nothing of lavish outlay in many other directions which vie in elegance with high-class hotels, as part of the equipment of a commercial machine shop or factory of any kind. They look upon such things with apathetic eyes, particularly when they see marble used in toilet rooms, libraries, and all the leading periodicals of the day supplied free to the whole force, when most of them never read anything except sporting papers when they read at all. All of the expensive outfit is, in a majority of cases, superior to that which the stockholders have in their own homes. It is considered by them as idle money which entails constant outlay for renewals, so one generation at least must pass away before a verdict can be rendered for or against the new departure. Every shop which is successful with the new method will encourage others, and similarly those which get along only vicariously will deter others; but it is quite safe to

say that, in the fullness of time the missionaries who are trying to "ring out the old" will reap their reward.

In corroboration of these views may be cited the case of one large factory which has existed for over a quarter of a century, and in the course of that time has tested many new systems of management, but has discarded all of them and returned to primitive conditions, or those in vogue from time immemorial, and is running as an old-fashioned shop pure and simple. It would be called dirty and in bad sanitary state. The closets are offensive even in cold weather, and the heating of the workrooms is spoken of bitterly by women who have to work in them. The rules and regulations for the maintenance of discipline are by no means liberal, while the penalties for infraction of them are summary dismissal after one warning. The daily task to be completed demands constant application to whatever detail is in hand, so that the output of every machine is known at the week end. The concern alluded to has a very large capital, so it is not lack of means which prevents them from adopting a better or more liberal system throughout, but results from experience with improvements, so-called, that did not pay anything, but took a great deal out, and were, therefore, discontinued.

This is the obverse of the medal, but it is apparent that there is a golden mean between lavish outlay for superfluities in shop outfits and pails of dirty water under the benches for men and women alike to clean themselves with. In one shop that I know of the lathes are painted with hard white enamel, and are as spotless as if they were to stand in a ladies' boudoir. There is some fitness in this which may not strike all observers, but it goes without saying that men will naturally handle such a tool with more care than they would one reeking with grease and dirt. I know of a marine engine

also which was painted a brilliant white from the bed-plate to the cylinder head, and woe be to the oiler who laid a grimy hand on it. They not only kept it clean, but they never dirtied it, with the result that the same care was taken in its operation, so that repairs were seldom required.

One fact should be borne in mind in the new-departure shops, some of them at least, and this is that the employees are not asked to contribute one penny of their earnings toward the cost of the privileges they enjoy, the installment of the plant being provided by the management, the only stipulation being that it shall be properly used; but it must be said that this is not always the case, particularly in the lavatories and closets, where the basins are, or have been, put to quite different uses than those for which they were designed. As a result, they cost so much for repairs that the manager removed the whole outfit and its belongings, retaining only that part demanded by the laws, and this of the simplest description that would answer.

"It is no part of our business, or intention, either," said the manager to me, "to make the toilet rooms so comfortable that the help will remain in them any longer than they have to. They loaf enough as it is, even when they lose their own time by it. Out of a force of thousands, many thousands, of workmen and women, suppose each one loses but one minute daily. It is big money in a week!"

Years ago the methods employed to hire workmen were different from those now in force. The custom was for men to enter a works by any passage open to them, the back fence mostly, for there was a watchman at the front gate with a stout cudgel, which he used on anyone that looked as if he wanted a job, or was at least going to ask for one, whether he wanted it or not, and drove him away. Another method

was to watch a chance at noon-hour to sneak in with others going back to work, or to waylay the foremen and do business with them.

In the course of time these methods were outlawed and a bench was put in the front hall where applicants for jobs were permitted to cool their heels until such time as the clerk in charge of the job deigned to notice them, when, if he happened to be in good humour, he would allow a man to see the foreman. This abuse of power came to the ears of the "bosses," and the men were allowed to ask for jobs direct. If a man wished to disqualify himself permanently from getting work, he would write to a foreman for a place, but he would never get one by that means, but acquire the reputation of a vain and forward person who sought to win favour by a display of "scholarship" which his mates did not possess.

All of which discursion from the main purpose of this paper is to set forth the method obtaining in one of the foremost shops of the new dispensation to recruit a desirable class of young men and women. Those who apply are given a form like the one shown on the next page, which they are required to fill out in duplicate, one on yellow paper, the other on white. One of these forms is forwarded as addressed, the other being retained on file in the office of the inquirers, and the reply, when received, is also put on record, as part of the archives in the case of the applicant. It is a voucher for the previous status of the man which he is expected to live up to, and is certainly a vast improvement upon the systems in use a long time ago of hiring men who were standing idle in the market place, without knowing anything about them except what they chose to tell.

Singularly enough, this last scheme was tried by a young man who fell heir, as one may say, to a worked-out claim of a shop that had been abandoned by its projector. The ex-

perience I am about to relate actually occurred. A manufacturer, finding himself saddled with a plant which he was unable to handle himself, was talking the subject over with a confidential clerk, and between them they evolved the following scheme, which seemed worth trying:—

The manufacturer was to underwrite the enterprise to a certain amount and the clerk was to be general manager of it. The clerk knew very little more about running the practical part of the business than the manufacturer did, but he had ideas which he proceeded to carry out. The factory was a large one, of five floors, and was well equipped for making a staple article for which there was a regular demand the year round. On each floor the manager installed a superintendent machinist, who had constant oversight of all the men, and saw that the machines never stopped turning out details through every hour of the working day. He started every machine himself promptly on the hour as fast as he could get to them, and they never stopped except at regular times, or when something went wrong with them. When this happened the foreman machinist rectified the trouble without delay. Thus production never ceased.

If a man showed inaptitude for any particular branch of the work he was shifted about until he got into the right one. If too many drills were broken by a man with more strength and zeal than was necessary, he was quietly told that the drills cost, say a shilling each, which naturally made him more careful; but if precept and admonition were useless with individuals, the one in fault was dismissed, an example which was not lost upon others.

It only remains to add to this incident that the scheme was peculiarly successful, but it would not work under all conditions,—for instance, those where regular ma-

EDWARD WESTON, PRES.

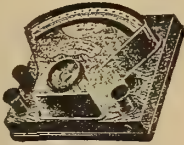
HENRY E. NIESE, Vice-Pres.

L. H. RUST, TREAS.

E. F. WESTON, SECY.

WESTON ELECTRICAL INSTRUMENT COMPANY,

MANUFACTURERS OF



Electrical Measuring Instruments and Appliances,

OFFICE AND WORKS, WAVERLY PARK, NEWARK, N. J.

Long Distance Telephone 1930 Newark.
Connecting all departments.

Cable Address, "WESLEC."

Telegraphic Code, "A. B. C."

WAVERLY PARK, NEWARK, N. J., _____

In your reply please refer to _____

_____ has applied to this company for
employment _____ and claims to have
been employed by you as _____
under _____
during _____

Will you please furnish us with the information requested below,
and greatly oblige,

Yours very truly,

WESTON ELECTRICAL INSTRUMENT CO.

Per _____

How long in your employ? _____ Date of leaving? _____

Occupation at which employed? _____

Were services satisfactory? _____ Does he apply self? _____

Honest? _____ Sober? _____ Capable? _____ Are you related? _____

Reason for leaving your employ? _____

Would you reemploy? _____

Remarks: _____

_____ Day of _____ 190 . Signed _____

chinists are employed, for these last would be restive under the constant oversight of a walking foreman, and would not put up with his interference with the tools. The men employed in the shop I have spoken of were only machine operators, as automatic as the machines themselves, and could be had at short notice when needed. As means to an end they answered all purposes. But since the once highly esteemed trade of the machinist has degenerated into one of an army of machine tenders, unskilled in any direction, except so far as ability is concerned to move certain levers at certain times, without any further interest in the output of the automata other than that their product should pass inspection, I do not see why such a force of handy men as that described in the last few paragraphs should not become common everywhere. They are more flexible in the administration of the shop, and will stand much more in dictation and reprimand when it is needed than a high-class, trained machinist.

To such accuracy have automatic

tools been brought that adjustments and niceties of fitting which had to be done with a fine file in the hands of a good fitter are no longer required. I pointed this out to the general superintendent of a pistol factory, and asked him how much handling had to be done to the parts after they came from the machines, and his reply was:—

"None at all. I'd like to see a man going over details with a fine file. But there will be a lot of jobs for the jig makers. How do you suppose a commercial watch can be made and retailed for a single dollar, leaving two or three profits for those who buy to sell again? For all the practical uses of life these watches mark time as well as those costing \$300, and they are all punched out of blanks by cheap labour."

The superintendent took me to an inspector, got one of his gauges and went to a machine with it, picking up a handful of small parts from it. "Try them," he said. "Are there any which require fine filing?" I was answered.



SMALL BRITISH STEAM ENGINES

By W. H. Booth

The present article is a fitting supplement to the one in our September number, dealing with "Small American Steam Engines." Professor C. H. Benjamin in that issue, and Mr. Booth here, tell and show excellently, with photographic aid, that the days of the small steam engine are still here, that there are many designs to choose from, and that the small steam engine business is likely to figure as an important one for some time to come.—THE EDITOR.

WHEN the large number of small gas engines that are at work in the world are taken into account, the thought naturally arises that but for the gas engines the small steam engine trade would have experienced a period of great activity. As it is to-day so much in competition with the trade in gas engines, one marvels where all the small steam engines really find a market. Yet the small steam engine is by no means dead; it is still made in its thousands, not merely in the form of the agricultural engine built into the same connected whole as the boiler which supplies it with steam, but also as a separate unit, to be driven by some fixed boiler.

Notwithstanding the economy of

the gas engine, the steam engine possesses one very important advantage over the small gas engine in the fact that it requires less skilled attention and will work after it has been allowed to run down to a condition in which the gas engine would absolutely refuse to work. Thus a slack piston will reduce a gas engine to a standstill, but a steam engine will run as long as the boiler will send steam to it.

To the mechanical man it is often distressing to see the condition into which machinery is allowed to fall, but the commercial engineer has to recognize that these bad conditions are part of the game, and that the constructing engineer has to do his work with these conditions before him. On many farms, for exam-

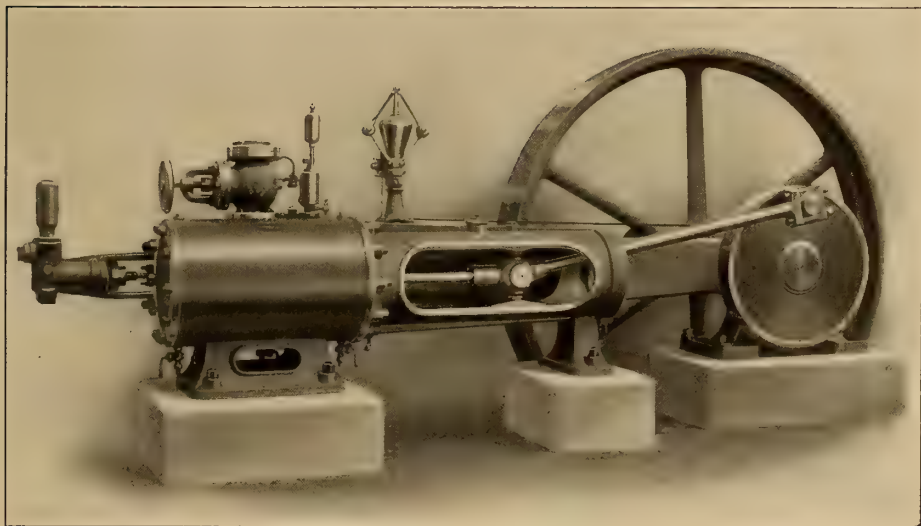


FIG 1.—A TYPICAL TANGYE ENGINE, BUILT BY TANGYES, LTD., OF BIRMINGHAM

ple, when an engine has done its work for the season, it is simply left as it came to rest and is expected to start up next year as though no time had elapsed since it was last at work. Thus an engine will be left idle for months with its piston rod enveloped in the wet packing of the stuffing box which by rights ought to be removed and the rod painted with a protecting substance when a sea-

son's work is over. Water is left in the cylinder to rust away the piston rings, and engines are frequently left exposed to the weather. This bad treatment cannot be provided against by a designer, but it points to the need of simplicity of design, and goes far to explain why the slide valve holds its own in the small engine trade. It is a disadvantage, from an academic view, that the steam engine will run as long as it can hold together and can get steam, but this fact is its salvation.

At one time the small steam engine might have been considered as confined to sizes not exceeding a 10 to 12-inch cylinder, but to-day one might class as small all engines up to 16 and perhaps even 20 inches cylinder diameter, while the higher pressures common to-day enable very considerable powers to be derived from a so-called small engine, and the larger sizes among them have found a considerable field of utility in the driving of electric light machinery at isolated country houses. Such engines do not come under what may be termed agricultural or farm conditions, but receive all proper care and are supplied with attachments and refinements equal to those of any factory engine. The small steam engine, as a class, thus comprises a varied assortment of machines, from the simplest of single-cylinder, non-condensing engines to compound engines, which may be of the condens-

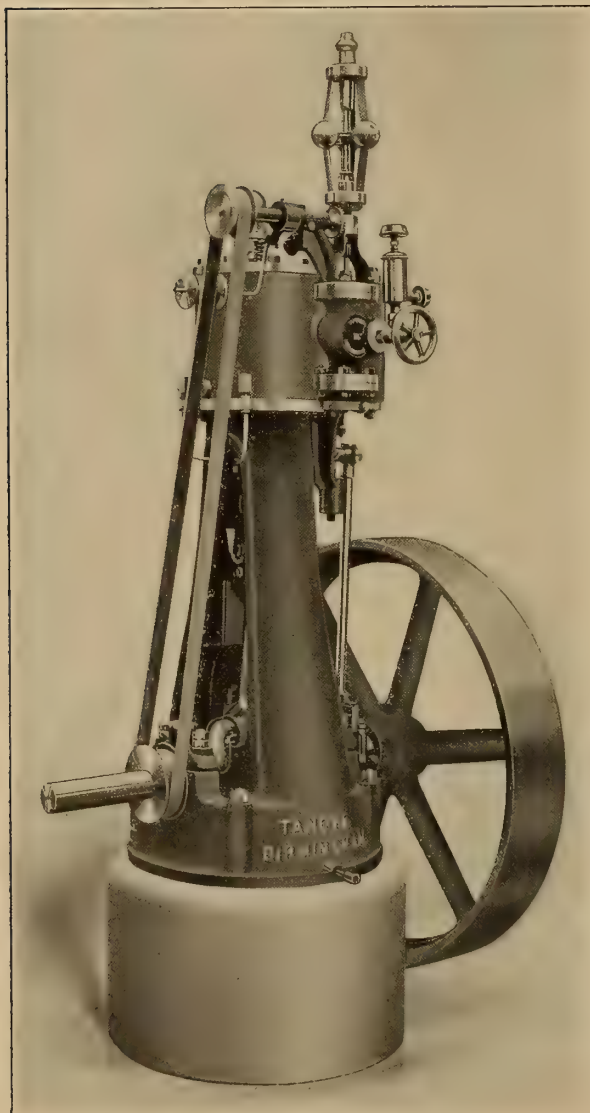


FIG. 2.—A VERTICAL TANGYE ENGINE

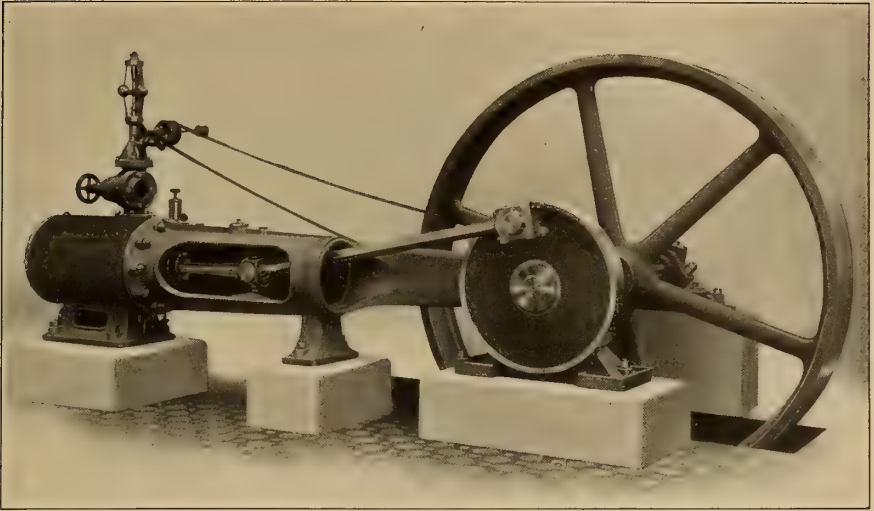


FIG. 3.—A TANGYE ENGINE WITH PICKERING GOVERNOR

ing type, though they then begin to be scarcely fit for inclusion under the generic head of small engines.

To build up a small steam engine business means great attention to the exigencies of manufacturing. The time has gone by when a steam engine was built into its surroundings as a kind of architectural feature of the landscape, every engine having individual characteristics. Small engines are made in quantity. They are all alike and interchangeable when of the same size and by the same maker. The details which go to their making-up are machined to gauge and template and put into bins, whence they are given out in lots of twenty or fifty, as required for the making of each fresh lot of engines.

To prevent too great a multiplicity of parts, the designer must try to build up his units of 5, 10, 15, or 20 horse-power into multiples of such units by the use of a minimum number of patterns, and the same framing is made to do duty for perhaps two or more sizes of engine and other details are kept down in number. It is necessary in all machinery to give additional strength above the net requirement. This fact enables

the designer to effect the above economies, and he is the best designer who can carry out this principle without introducing in the completed engines a disproportionate appearance of strength in any one size of engine.

As an example of this, in a catalogue before me there is a table of twelve sizes of engine, but with only six diameters of fly-wheel and only six lengths of crank. Another table of fourteen sizes of cylinder has six different cranks and six fly-wheel diameters. Then the addition of a condenser will demand no change to an engine except a tail rod and cross-head to drive the air pump, which will be placed vertically behind and below the engine platform, self-contained with the condenser on one bedplate.

In the British small steam engine trade there is no firm better known than Tangyes, Ltd., of Birmingham. Though large makers of suction gas producers and gas engines, their trade in small steam engines appears to progress undiminished, which would seem to show that the general demands of the world are increasing. In Fig. 1 is shown one of their 12 × 24-inch engines, which is

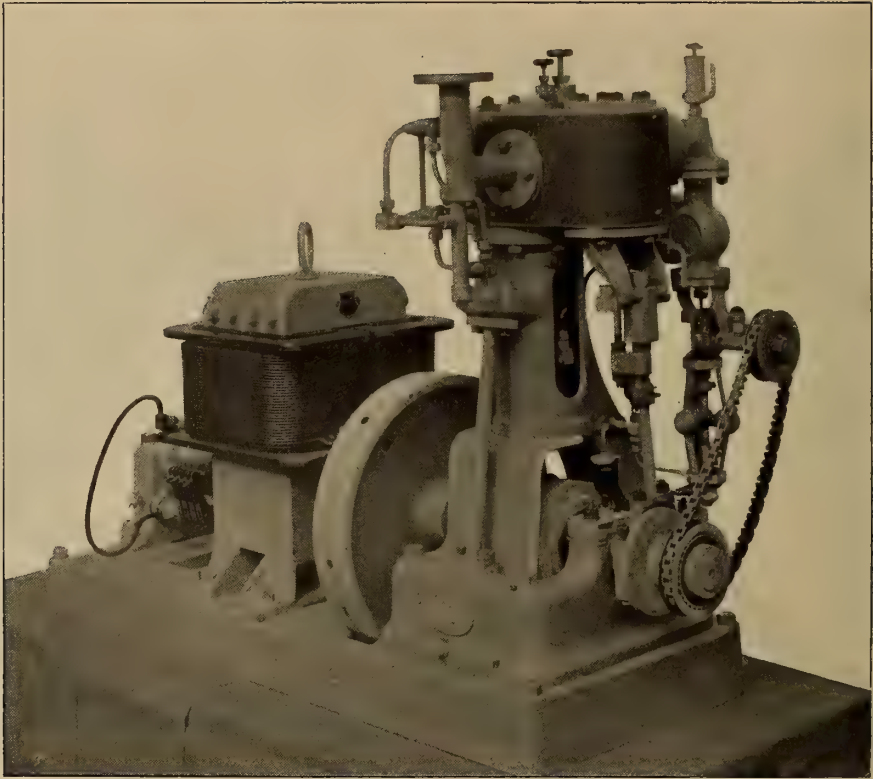


FIG. 4.— HIGH-SPEED ENGINE AND DYNAMO, BUILT BY MESSRS. MARSHALL, SONS & CO., GAINSBOROUGH

about the middle member of a class of engine that is built in nine sizes, from 8 in. $\times$ 16 in. to 18 in. $\times$ 36 in., and, therefore, fairly representative of the small engine. The speed of the engine illustrated is 95 revolutions, and the speed of the class varies from 125 for the smallest down to 70 for the largest of the class.

The prominent feature of this engine is the Tangye-Johnson automatic cut-off gear controlled by a Porter governor, but the feature of more historic interest is the engine framing, which was originated by the Tangye firm, but is often erroneously credited to Corliss, who adopted it for the Corliss engine. The cylindrical part of the frame can be bored out, and is fitted with cylindrical cross-head slides, thus greatly simplifying construction, as well as

forming a convenient girder frame. The disc crank is also a well-known Tangye feature. It is a part easy to manufacture, carries its own balance weight cast in, and has features of safety which are absent in the ordinary crank, for the rim of a disc crank is a constant guard against the insertion of a foreign body where it can be caught by the crank.

Except in the smaller sizes, Messrs. Tangyes, Limited, provide their horizontal engines with jackets. The crankshafts are of steel, the connecting rods of hammered iron, a feed pump is fitted, if required, and superheated steam may be used up to 400 degrees F. where the valve is the plain, flat, unbalanced slide, but for piston valves, engines that will use steam as high as 650 degrees are made, the piston valves working

in renewable cast-iron liners. Such an engine as that illustrated will give 52 H. P. if worked non-condensing with steam of 100 pounds boiler pressure, and the steam consumption will be 26 pounds per I. H. P.-hour.

A point to be considered by the designer of an engine is so to arrange his design that at a minimum of expense an engine may be built either right or left-handed, a right-handed engine being one in which, while standing behind the cylinder, the crank disc is to the right and the fly-wheel to the left, or when standing so that the crank is to the right and the cylinder to the left, the engine has its front or open side towards the spectator. This Messrs. Tangyes arrange to do.

The small 6 in. $\times$ 6 in. engine shown in Fig. 2 is the same firm's make of small vertical engine, in which the same construction of frame is adhered to so far as possible with the difference of type. This little engine is made in seven sizes, from 4 in. $\times$ 4 in. to 10 in. $\times$ 10 in., or with cylinder differences of 1 inch, with speeds of 320 to 180 revolutions per minute. It will develop from 3 to 26 horse-power with 100 pounds pressure above atmosphere, and, while available for general work, would not be considered suitable for electric lighting work, for which purpose, in place of the quick-speed governor, there would be an automatic crankshaft governor and a heavier fly-wheel, and the speed would be higher, or from 250 to 450 revolu-

tions; and, for heavier work still, two such engines would be combined on a common bedplate so as to get, with the 10-inch size, as much as 80 brake-horse-power, and even more, if necessary, by raising the speed by 50 revolutions by removal of a weight plate, or plates, from the

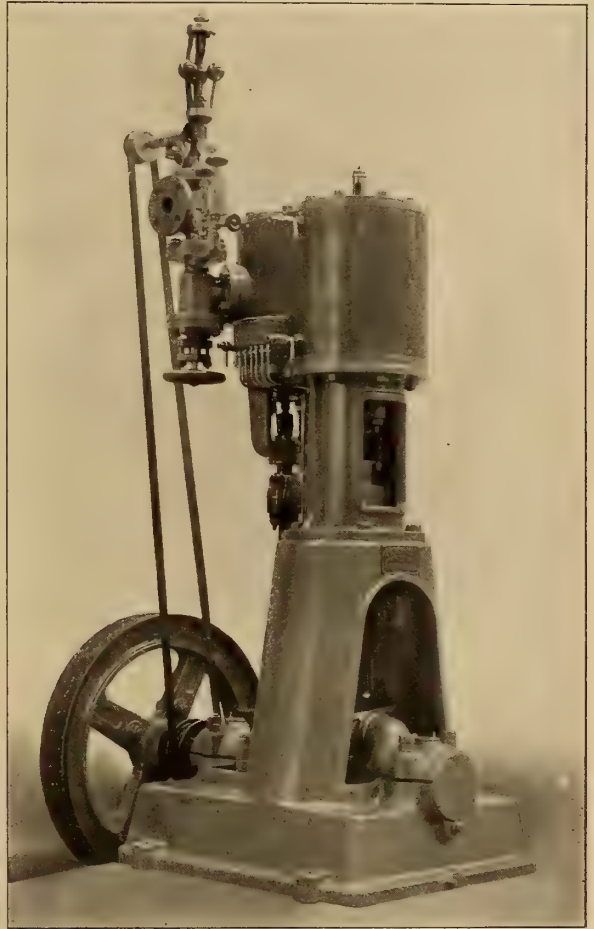


FIG. 5.—BENT-CRANK ENGINE, BUILT BY MESSRS. SAMUELSON & CO., LTD., BAURY

fly-wheel governor. In the case of a pair of engines the fly-wheel runs between them, but the crankshaft projects at either end and can be fitted with a gear wheel or a belt pulley.

While, therefore, the regular horizontal engine preserves the old ratio

of diameter to stroke of 1 to 2, the small verticals are what are often technically called square engines, having the ratio 1 to 1; but in the "Colonial" engine, which is a specially stiff type, with bent steel crank and two bearings, the ratio becomes 1 to $1\frac{1}{2}$, as nearly as even inches can be thus arranged, and there are seven sizes from 5 in. $\times$ 7 in. to 12 in. $\times$ 18 in., and from 125 to 250 revolutions, while the "Soho" horizontal

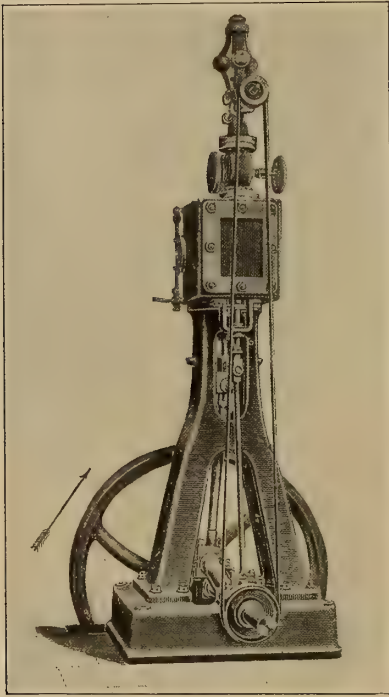


FIG. 6.—ENGINE MADE BY MESSRS. ALFRED DODMAN & CO., LTD., KING'S LYNN

engine is "square," and has a double disc crank enclosed in the casing, which is divided diagonally for removal of the cover. This engine is, therefore, almost enclosed, being open only along the path of the cross-head.

Then engines are coupled as side-by-side compounds with the air pump on the tail rod of the low-pressure cylinder, and, as tandem compounds, with tail rod air pump, or the engine may be non-condens-

ing. Though Tangyes, Limited, have brought their designs up to date and make their new standard horizontal girder frame engines in all sizes and combinations to stock, there are users who still stick to their old form with continuous base bed and cylinder overhung behind the frame, and this well-known engine is, therefore, still made when required.

Indeed, this old type of Tangye engine has made for itself a name, and will simply not be put out of the running by any new design. This is a tribute to its sound and simple design, and reminds us of an old engineer, who, when freak engines were once the topic of discussion, declared that a steam engine needed a cylinder, a rod, a connecting rod, a crank and shaft, and a simple valve gear. It would not run well without these few necessities, and it did not require anything else. There was a good deal of truth in this, and as men grow old in experience they appear to lose faith in contraptions and come back to simple fare.

In Fig. 5 is shown a bent-crank engine of vertical type, as made by Samuelson & Co., Ltd., of Banbury, the general feature of design being the straight-line, direct thrust principle; of the details, the lubricating box and pipes to various points will be noticed, and the general stiffness of the engine comes out well in the illustration.

Stiffness is a feature also in the engine of Fig. 4, which is built by Messrs. Marshall, Sons & Co., Ltd., of Gainesborough, for high-speed electric work. In this engine may be noted the pitch claim driving of the high-speed governor and the method of supporting the cylinder on the front side by a steel pillar, which can be removed so as to leave the crankshaft open and accessible by removal of the light splash guard.

The chain-drive of the governor is considered to add reliability and positiveness of speed, and is a feature also of the above firm's horizontal

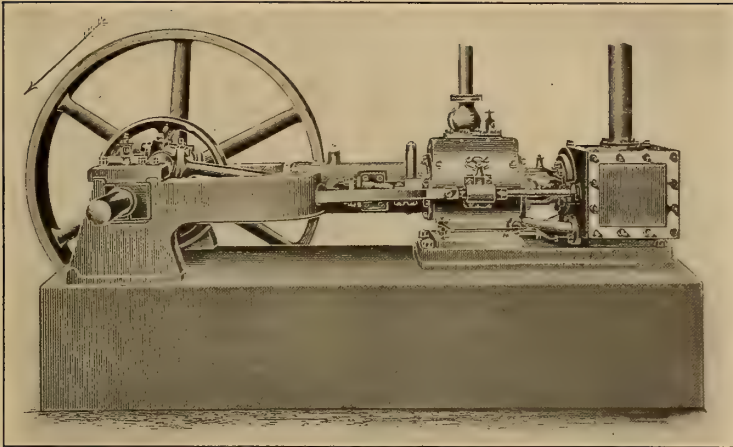


FIG. 7.—A TANDEM-COMPOUND ENGINE BUILT BY MESSRS, ALFRED DODMAN & CO., LTD.

engines, which are a compact, flat-bedded type with overhung cylinder and bent crankshaft, in sizes from $4\frac{1}{2}$ inches to 11 inches diameter of cylinder, fitted, like the vertical engines first described, with the Pickering governor, and equilibrium throttle valve, and suitable for working up to 100 pounds for simple and 150 pounds for compound engines, for which, however, the Hartnell governor is supplied to actuate an automatic expansion gear. Many of the small engines of this firm are made with trip gear and drop valves for automatic variable expansion, and may be classed as small engines in the smaller sizes, for the same general construction is characteristic of engines from 7 in. and 13 in. $\times$ 20 in. up to 22 in. and 38 in. $\times$ 48 in., and they can be made condensing by the application of a tail rod air pump combination worked direct, or by an *L* lever in the case of the so-called "downstairs" type, in which the air pump stands on a floor level with the bottom of the engine foundation block.

As an example of a really small class of engine, Fig. 6, of Alfred Dodman & Co., Ltd., of King's Lynn, may be given. From 4 inches to 13 inches diameter, with strokes of 6 inches to 18 inches and

a speed of 240 to 100 revolutions, these engines are of general utility, are simply made, and may be combined on one bedplate with a vertical boiler. They have an equilibrium throttle with Pickering governor.

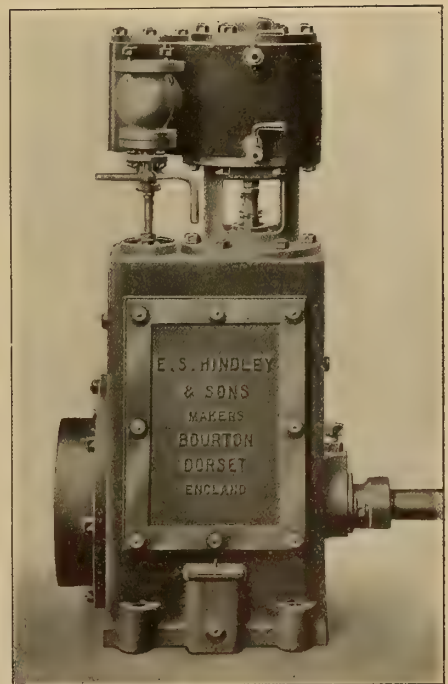


FIG. 8.—ENCLOSED ENGINE BUILT BY MESSRS, E. S. HINDLEY & SONS BOURTON, DORSET

For heavier work, the same makers have the compound tandem horizontal engine of Fig. 7, with double girder bed and a drum governor for automatic expansion, and plain valves.

No doubt many engineers have had occasion to prove the excellence of the small engines of E. S. Hindley & Sons, of Bourton, in Dorset, for driving well pumps and for general country purposes. In Fig. 8, however, this firm have a quite new design of small high-speed enclosed engine of stout build, with a distance piece between cylinder and pedestal trunk, and a bored cross-head guide and cut crankshaft, which can be removed through the cover opening. The mistake of small openings into the crank chamber is avoided, for the whole side can be thrown open by unbolting the cover

plate. The crankshaft governor runs in an oil bath, and the engine is designed for dynamo driving more particularly.

Among the newer makers are Messrs. Easton & Bessemer, of Taunton, and their high-speed engine is shown in Fig. 9. This particular illustration is from an engine 8½ in. and 14 in. × 6 in., to run at 550 revolutions a minute, the combined engine and dynamo occupying a floor space of 10 ft. 3 in. × 4 ft. 4 in., and giving 80 brake-horsepower and an electrical output of 280 amperes at 210 volts. In this engine, which is characteristic of the general form into which survival and general fitness seem to have moulded the high-speed engine, the valves are of the piston type. Balancing is attended to by making the high-pressure piston of cast iron and the

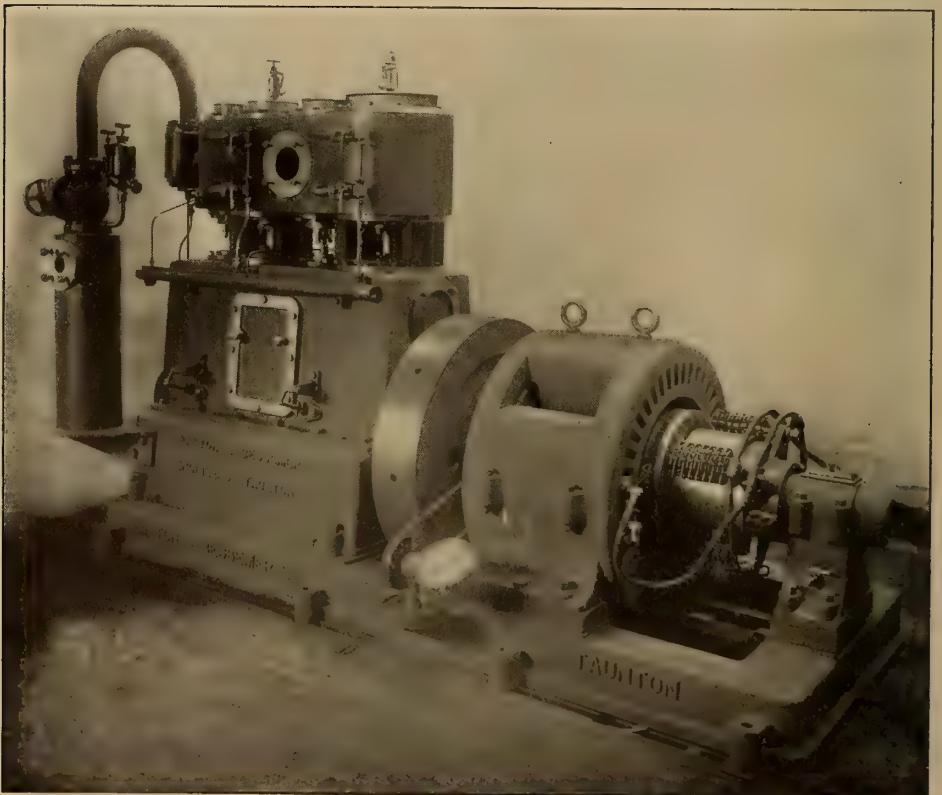


FIG. 9.—HIGH-SPEED ENGINE AND DYNAMO BUILT BY EASTON & BESSEMER, TAUNTON

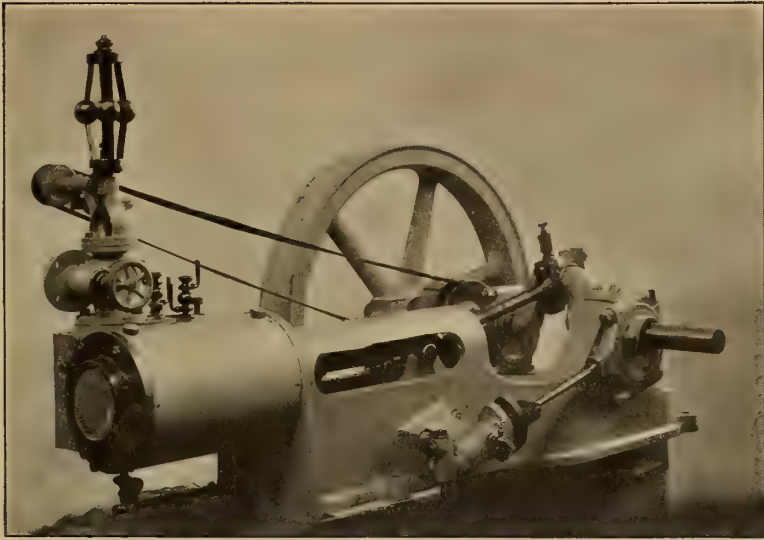


FIG. 10.—"JOHN BULL" ENGINE, BUILT BY MESSRS. E. R. & F. TURNER, LTD., IPSWICH

low-pressure piston of cast-steel, and economy is sought by machining bright both pistons and covers, and there is forced lubrication to all bearings and pins. The usual details and accessories of high-class engines are present, with crankshaft governor claimed to regulate to 3 per cent. between full and no load, a speed regulating gear which will vary the engine speed 10 per cent. while running, and anti-friction bearings to the crankshaft, which has four bearings in the case. The particular engine illustrated runs with superheated steam of 150 pounds pressure.

An engine of stiff and compact build made by Messrs. E. R. & F. Turner, Ltd., of Ipswich, is that of Fig. 10, known as the "John Bull" engine. It is a general utility engine, designed to meet the demand for a strong engine at a moderate cost to run with fairly high boiler pressure, up to 100 pounds, and self-contained, so as to be ready to be dumped down on a smooth-top bed, bolted flat, and set promptly to work. Its general construction is clearly shown, and it exemplifies the distinction between the small steam en-

gine of to-day and that of not many years ago, which was but an overgrown specimen of the thing that

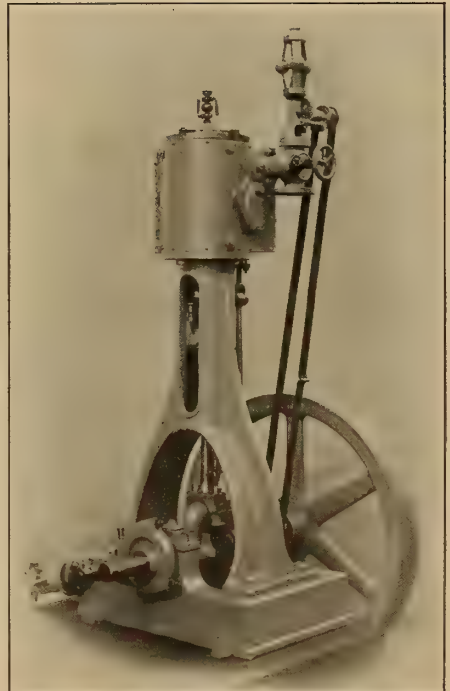


FIG. 11—A VERTICAL TYPE OF TURNER ENGINE

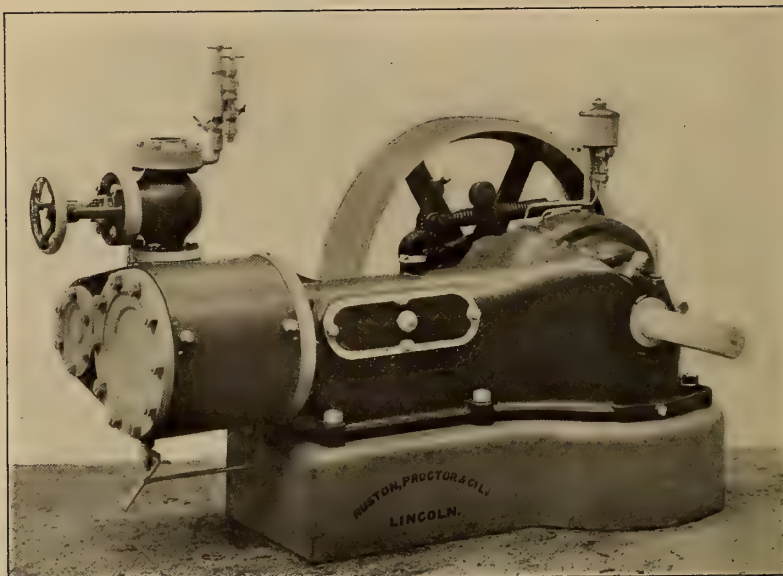


FIG. 12.—ENCLOSED ENGINE BUILT BY MESSRS. RUSTON, PROCTOR & CO., LTD., LINCOLN

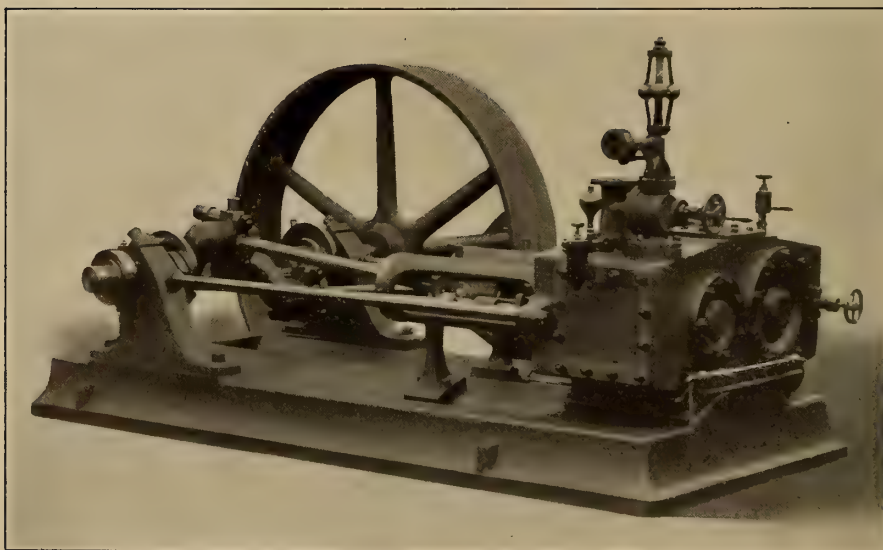


FIG. 13.—A COMPOUND ENGINE BUILT BY MESSRS. BROWN & MAY, LTD., DEVIZES

schoolboys were wont to make and the early students of evening science and art classes were set to draw.

These "John Bull" engines weigh, complete, 8 cwt. for the 5 in. $\times$ 7½ in. size; 57½ cwt. for the 12 in. $\times$ 16 in. size; and they will give off at the fly-wheel rim from 7 to 40 horse-power with steam at 100 pounds. This pressure of 100 pounds may be stated to be the usual pressure at which the simple small engine is made to work, and, considering the sort of attention given to steam boilers in the country, and the strange sort of men that Board of Trade inquiries have shown to have had charge of exploded boilers or to have been considered able enough to examine them for safety, this pressure is probably quite sufficient. Fig. 11 shows the extremely neat vertical form of the same maker's engine of 6 in. $\times$ 9 in. size.

Fig. 12 shows the design of Messrs. Ruston, Proctor & Co., Ltd., of Lincoln, for a small enclosed horizontal engine, the crank chamber being a part of a general box frame with a diagonally bolted cover, easily removable for inspection of the crank and pin. This is an extremely stiff little engine with fly-wheel, governor, and piston valve, large bearings and general high-class make, suitable for pressures up to 160 pounds, at which the 5½ in. $\times$ 8 in. size will give 25 I. H. P. at 350 revolutions, non-condensing. Lubrication is provided, for long runs, from a central oil box, and the high speed of the engine permits of its use for electric light work. In Fig. 14 is the design of the same makers for a similar class of vertical engine.

As a light and yet strong compound engine, that of Messrs. Brown & May, Ltd., of Devizes, shown in Fig. 13, may be cited. In this engine the cylinder and guides are attached, but are not in one with the crank pedestals. These, however, are joined in the direct line of stress with the cylinders by steel rods, and there is a double-throw crankshaft

of bent steel bar, a broad fly rim, Pickering high-speed governor, and a complete rectangular flat bed, the whole forming a not unpleasing combination, the smallest size having cylinders 7 in. and 12 in. $\times$ 12 in. stroke, and running at 180 revolutions with 140 pounds of steam and developing 36 effective horse-power. The cylinders are cast together, and

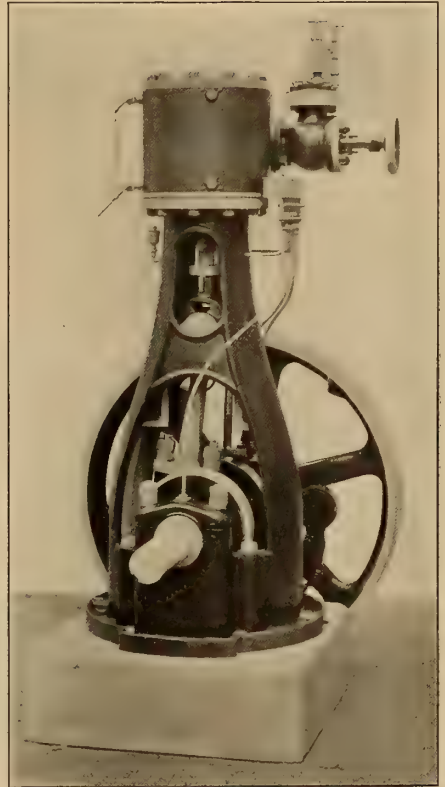


FIG. 14.—A SMALL VERTICAL ENGINE. BUILT BY MESSRS. RUSTON, PROCTOR & CO., LTD., LINCOLN

the high-pressure cylinder is fitted with a piston valve, a flat slide being supplied to the low-pressure side. The flat bedplate greatly facilitates erection.

Though in the foregoing engines most of the types in use have some exemplar, they by no means exhaust the list of makers. All the agricultural engineering firms make small steam engines. Usually they

are attached to the boiler, or, in more powerful engines, the engine proper is under the boiler on a common bed-plate. But these engines are on the general lines of those illustrated. Often they have the link valve gear, and will run either way round. Of this type is the engine of the traction engine and of the road roller.

Electric driving has not done so

much as is sometimes thought in the way of eliminating the small steam engine. True, it has abolished it where a single large machine had to be driven, for a small steam engine was once built into these large machines. What the electric motor has displaced particularly is the shaft and the belt, or toothed gear,—what one may term millwright work.



SOME RECENT ADVANCES IN THE APPLICATION OF COMPRESSED AIR

By W. L. Saunders, M. Am. Soc. C. E.



THE last few years have witnessed a marked advance in the economical application of compressed air. Compressed air has never enjoyed a reputation for economy,—that is, mechanical economy, as distinguished from commercial economy. That compressed air has been so widely used

has been due almost entirely to the fact that no other medium would accomplish the same results. If, for instance, electricity could have been applied to the operation of rock drills, chipping hammers, and other tools for which compressed air is used, there might have been a marked saving in the cost of operation. But, owing to mechanical difficulties, electricity has never been successfully applied to work of this kind, and compressed air, consequently, remains the motive power par excellence for rock excavation and the operation of many portable labour-saving tools.

Economy has been brought about in three ways,—using compressed air expansively, reheating it, and last, but perhaps most important of all, combining forces with electricity as exemplified in the “Electric-Air”

rock drill and the electro-pneumatic railway switch.

Using compressed air expansively and the installation of reheaters naturally go hand-in-hand since, as a general rule, it is impracticable to obtain any considerable degree of expansion in a compressed air engine unless the air be heated to a high temperature before admission to the cylinder. The curves shown in Fig. 1 illustrate this quite clearly. It will be seen that even if air under 100 pounds pressure be admitted to a cylinder at a temperature of 200 degrees Fahr., the resulting temperature, after expansion to atmospheric pressure, will be nearly 100 degrees below zero; and, in order that the air may be expelled at a temperature which will prevent freezing at the exhaust, it must first be heated to a temperature in excess of 450 degrees Fahr.

From the foregoing, it may appear as though the function of a reheater is purely to enable the full expansion of the compressed air. Such is not the case, however, as reheating possesses another and more important advantage; it increases the volume of the air and makes a greater quantity available for doing useful work.

Now let us see how far these principles have been carried out in practice and what advantages have been derived therefrom.

Within the last few years the Cleveland Stone Company, at its North Amherst, Ohio, quarries, has transformed its entire transmission equipment from steam to compressed air, the latter being produced in a

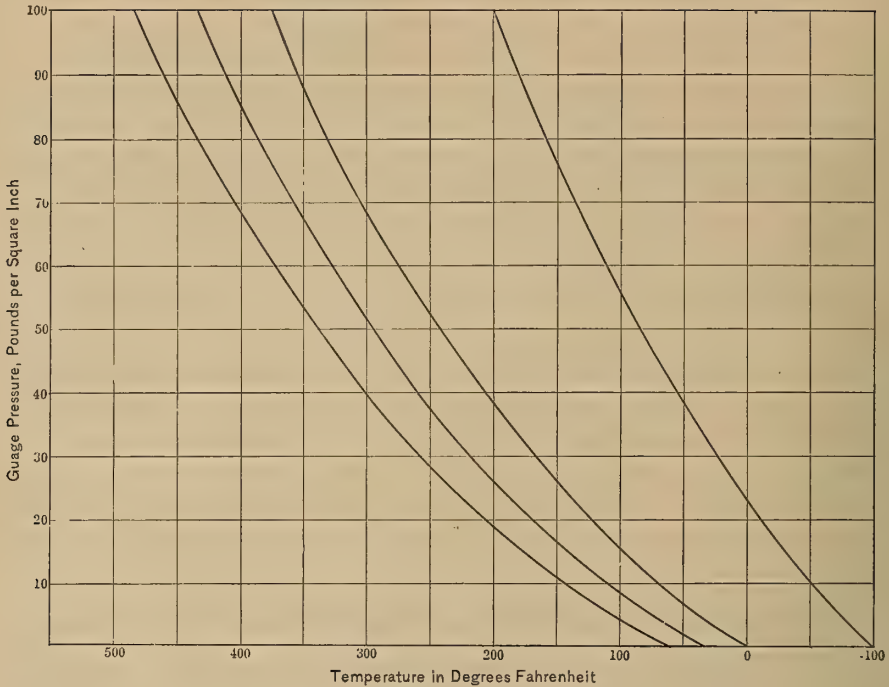


FIG. 1.—ADIABATIC EXPANSION OF AIR. TEMPERATURES REACHED IN EXPANSION FROM VARIOUS GAUGE PRESSURES TO ATMOSPHERE

central power plant under the most economical conditions. The channeling machines used by this company are all fitted with the most approved form of reheater, and the plant is, therefore, a fair example of what an up-to-date compressed air installation should be. It is interesting to note the saving which was effected after the installation of compressed air. This is partially shown by the following table:—

BEFORE USING COMPRESSED AIR

	Per Day
Labour and attendance at channelers, sixteen machines, at \$10, =	\$160.00
Coal used, 50 tons run of mine, at \$2.....	100.00

AFTER USING COMPRESSED AIR

Labour and attendance at channelers, twelve machines, at \$10, =	\$120.00
Coal used, 15½ tons slack, at \$1.60.....	24.80

The reduction in the number of machines is entirely due to the installation of compressed air, it being found that the heavy and uniform pressure always available enabled these fewer machines to do

more than the work formerly done by the larger number when operating under the lower and fluctuating pressure of steam. This table, however, takes into account only the cost of labour and attendance at channelers, and does not in any way show the further and greater saving effected by the concentration of boilers and compressors under one roof and the elimination of numberless temporary and very uneconomical boilers scattered throughout the works.

So much for compressed air in the quarry. We now come to a later development in the economical application of pneumatic power, the "Return-Air" pumping system. Here we have a perfect example of the use of air expansively, with its consequent saving over the older and less scientific systems. There are a number of compressed air pumping systems in present use. There is the air lift system, in which compressed air is admitted to the lower end of

a submerged pipe, and, mixing with the column of water contained inside, makes this column lighter than the corresponding column of water outside the pipe, which, in turn, forces the water inside to the surface and maintains a continuous flow.

Then there is the compressed air displacement pump which operates by the direct pressure of the air on the surface of the water, forcing it out of a tank, admission to and discharge from which are controlled by check valves.

Another form of compressed air pump is the direct-acting steam pump operated by compressed air. This, probably, is the best known type of pneumatic pump, although not always recognized as such, and is largely used in mines. In order that the reader may have an adequate idea of the value of using compressed air for pumping water, it might be well to state here that the compressed air displacement pump has shown an efficiency of nearly 20 per cent., but even if this efficiency were cut down to 10 per cent. it would still be considerably higher than could be obtained if a common steam pump were used to do the work.

With the exception of the air lift, all the systems described are adapted to very much the same kind of work, i. e., pumping water from mines, rivers, pools or shallow wells. The air lift system is adapted only to the pumping of deep wells, and its successful operation requires that approximately 50 per cent. of the total length of discharge pipe be submerged.

We now come to the "Return-Air" system. This, like the other pumps described, is adapted to pumping in shallow places, it being necessary only to have the two tanks composing the discharge chambers partially or entirely submerged. This system is essentially and exclusively a pumping installation, and should be regarded as a permanent plant, the machinery being set with a view

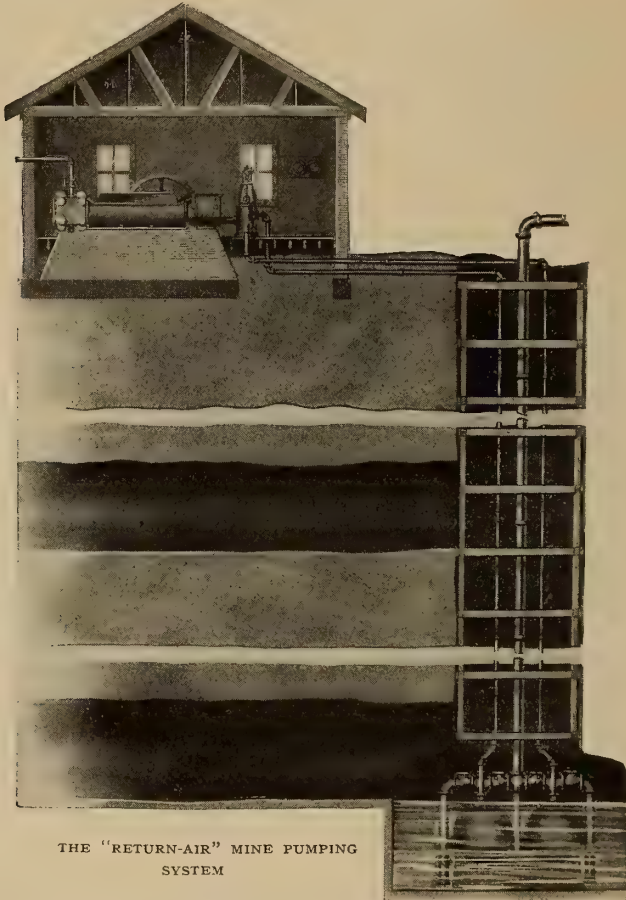
to securing the most economical conditions. The "Return-Air" system is, without doubt, the most economical of all systems of pumping, with the possible exception of the higher grades of crank-and-fly-wheel types of pumps, which, however, are not usually adapted to mine pumping.

The "Return-Air" system involves the use of two tanks, preferably submerged, to which are connected water inlet and outlet pipes fitted with check valves. Two air pipes lead to the upper part of the tanks or chambers from a switch which automatically reverses the flow of air from the compressor in such a way that while the water in one tank is being forced out, the other tank is filling and the discharged air is returned to the intake of the compressor. It will be seen, therefore, that the full expansion of the air is obtained and that the energy is conserved to the greatest possible degree. The return air, entering the compressor under pressure, exerts its force upon the receding piston and supplies a part of the power required for compressing air on the pressure side. The additional power to be drawn from the engine is, therefore, only that required to make up the difference between the pressure of the air entering the compressor and that required to lift the water. There is some loss of air due to absorption by the water which must be made up from time to time, and a small valve is inserted in the compressor allowing a suitable amount of air to be drawn from the atmosphere during the suction period of the cycle.

In a paper read recently before the Coal Mining Institute of America, Mr. A. W. Patterson, Jr., states that the efficiency of the system depends upon the ratio of volume of the air tanks to the air lines, and that under normal conditions it is safe to say that an average efficiency of 55 per cent. may be secured. Installations have returned, under fa-

vourable conditions, as high as 63 per cent., and never, under unfavourable conditions, less than 50 per cent., this efficiency being the ratio of the horse-power of water lifted to the indicated horse-power in the steam cylinders of the air compressor and including all losses.*

apt to enter a mine pump, without impairing its operation. In the case of pumping flooded workings, the tanks of the system may be placed on a mine cage and lowered through the shaft, making the pipe connections as the tanks are let down, it being possible to pump dry in this



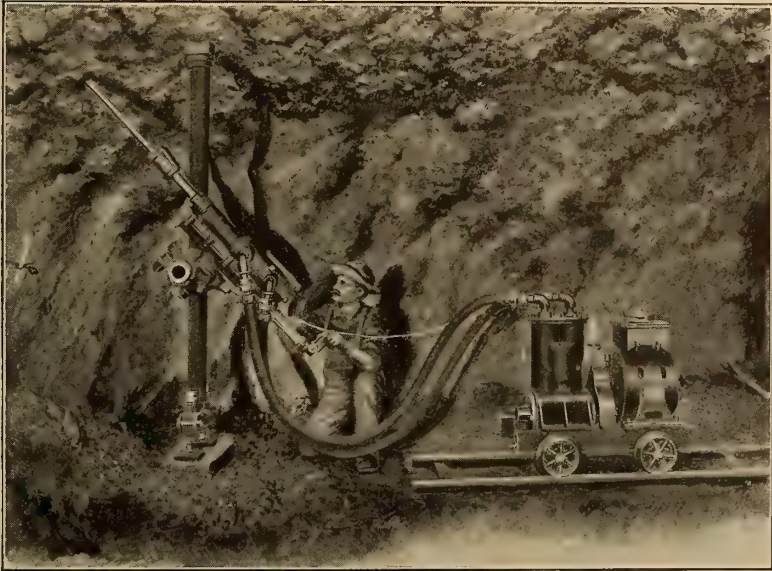
THE "RETURN-AIR" MINE PUMPING SYSTEM

Aside from the economy of the system, however, numerous other advantages are connected with its installation. It will pump any material that will pass through the valves of the system, such as sand and marl and such silt and dirt as would be

way, performing at one setting the long operation of lowering the water by means of sinking pumps.

Another important advantage possessed by this system in mining is the fact that the underground mechanism needs absolutely no care outside of occasional inspection. The services of a man underground are not required, and the repairs necessary to steam pumps are eliminated. The control of the entire system is concentrated

* See "Mine Pumping by Compressed Air." A paper read at the Pittsburgh meeting of the Coal Mining Institute of America, June 19 and 20, 1906, by A. W. Patterson, Jr. Also "The Return Air Pumping System," by Frank Richards, M. Am. Soc. M. E., published in "Compressed Air," August, 1906.



THE "ELECTRIC-AIR" ROCK DRILL

in the engine room under the eye of the engineer, who is in a position at any time to start and stop pumping or to vary the quantity of water lifted. Furthermore, there is no possibility of drowning out the system after it is once properly installed, as it will operate with less power in proportion to the height of water above the pumping tanks.

After the "Return-Air" pumping system, the third and most important advance in the application of compressed air is exemplified in the "Electric-Air" rock drill. It has long been recognized that as a medium for the transmission of power, electricity possesses many advantages over compressed air. It is more economical to generate, easier to transmit, and the cost of an electrical installation is considerably lower than that of a compressed air plant, with its expensive pipe line, fittings, and valves. In spite of all these advantages, however, electricity has never come into general use as a medium of power transmission in mines and quarries, for reasons already stated. It will be seen, therefore, that by combining the advan-

tages possessed by electricity with those of compressed air, a most important step forward has been taken, enabling the mine and quarry operators and contractors of the present day to install a system of power transmission which will compare favourably with any in general use.

The "Electric-Air" rock drill is exactly what its name implies,—an air drill operated by electricity. But it is not an "electric drill" in any sense of the word, this term being generally applied to drills in which the electric power is applied directly to the percussive mechanism. In the "Electric-Air" drill there are two separate and distinct features,—the compressor or pulsator and the drill. The pulsator is the part involving the use of electricity. It is a duplex single-acting machine, but differs from the ordinary air compressor in that it possesses no inlet or discharge valves. It is electric-motor driven through gear wheels, the motor being encased in a dust-proof casing, the whole being mounted on a steel truck which may run on the mine track or simply roll on the ground.

The drill closely resembles the or-

dinary type of compressed air rock drill, except that it is free from many of its complicated fittings. There is no valve, valve chest, valve motion, buffers, etc. It is by far the simplest rock drill ever built, practically a plain cylinder with a piston in it, mounted on a standard column, shaft bar, or tripod.

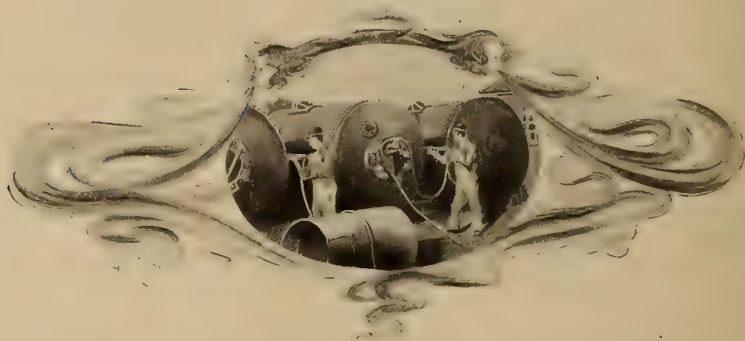
It is in the transformation of electrical energy into mechanical energy that this drill differs from other drills operated by electricity. Here, compressed air,—unbreakable and unwearable,—takes the place of the mechanical connections hitherto used between the rotary motor motion and the reciprocating piston action. Impulses of air under a constant pressure of 30 to 40 pounds are transmitted to the drill from the pulsator pistons through two short lengths of hose, each leading to one side of the drill piston, but so connected as to leave a protecting air cushion at each end. Thus an impulse from one pulsator cylinder throws the piston forward; the impulse from the other throws it back. The

air is not released or exhausted, but is used expansively, over and over again.

With the "Electric-Air" drill, therefore, there is no piping in the mine, and the full advantage of the more economical and efficient electrical transmission is realized. Furthermore, in the pulsator, the air expanding in the cylinder after compression cools the parts so that no water jacket is required and no trouble can arise from freezing in open work in cold weather.

The full significance of this invention is made evident when it is stated that the new type of drill requires in the driving of the generator only 5 horse-power for its operation, while the ordinary compressed air rock drill of equal capacity requires for driving the air compressor from 15 to 20 horse-power.

In the writer's estimation, the invention of the "Electric-Air" rock drill represents the most important step forward in the economical application of compressed air to modern industrial requirements.



ELECTRIC CABLE TROUBLES

By J. H. C. Brooking, A. M. I. E. E.

In connection with what Mr. Brooking here says, it is to be noted that in the United States nearly all underground electric cable work is done with earthenware conduits, iron pipes, some fibre conduits, and wooden pump logs. About the only instances where the cables are laid "solid" are those of the Edison pipe system. Practically everything is laid on the "draw-in" and "draw-out" plan. Even in Great Britain very many earthenware conduit systems have been put down in recent years, but the solid conduits have the preference in British practice, the cables being laid in trenches, and the insulating material being poured over them.—The Editor.

IT is not an uncommon experience to be placed in an awkward and sometimes embarrassing position by a temporary failure in the supply of electricity. The usual explanation is that a fuse has gone, and those who are thereby put to inconvenience say nasty things about that fuse and its responsible attendant. In nine times out of ten, however, the fuse has merely done its duty by announcing to an ungrateful assembly that something was wrong, and possibly by its act of extinction has saved the property or even the lives of its detractors. The real cause is, in most instances, the cables at some point or another, and the proper culprit for anathema should be the man who designed or installed those cables more or less badly.

Such inefficiency in workmanship is not always due to carelessness. It is often a lack of knowledge of one branch of electrical work on the part of an otherwise skilled and careful engineer. Men who design or are responsible for the erection of work in connection with the use of electric power in mines, factories, public institutions, and elsewhere, have often to be so many-sided that it is impossible for them to be experts in every branch of their work, and by reason of the seeming rope-like simplicity of electric cables, with their lack of machinery, such men occasionally come to grief when dealing with the question of electrical dis-

tribution. Sometimes it is the desire to economize that is at fault, but more often it is, as Dr. Johnson admitted to the lady who questioned an inaccurate statement in his well-known dictionary, "Gross ignorance, madam!"

There are three stages in connection with electric cables at which it is desirable to have considerable experience or to obtain expert advice. The first is the design of the cable itself as regards size of the conductor, class of insulation, method of construction, and manner of protection. The second relates to the system of laying and joining to suit the circumstances of the case. The third deals with the maintenance, which, though not of immediate importance in the early days of an installation, is of great and increasing value as time goes on.

At all these stages mistakes have been made in the past, and much trouble has been caused. The items may be taken in their order, so that where experience or advice is otherwise unobtainable, some ideas may be gained on the subject by the engineer unused to the problems of electrical distribution.

In selecting the class of cable for use, the size of conductor first claims attention. The problem is to estimate a size which shall not be so small as to waste too much energy, and possibly damage the insulation by the heat thus generated, nor so large as to waste capital. In public

electricity supply the sizes of mains are mostly governed by pure guesswork and rule of thumb, as it is impossible to tell beforehand what consumers or amount of current will be obtained in any street or district. Practical experience alone is of use in such a case. With cables used for more or less private purposes, however, it is easier to anticipate the average load, and to calculate the maximum load, with its duration. These are two important factors in deciding upon the size of the conductor.

If, for instance, an installation is fitted with motors, lamps, etc., up to a total capacity of 1000 amperes, it is most likely that the maximum load will be less than 800, and that for a very short time. Also it is likely that the average load during working hours will be between 300 and 500 amperes. Some people, with the dread of melting insulation in their minds, would in such a case provide a cable to carry the 800 amperes at a current density of 1000 amperes per square inch, i. e., an 0.8 square inch cable, irrespectively of the disproportionately small loss of energy at average loads of perhaps long duration, whereas with paper-insulated cables it is perfectly safe to run at 2000 or 4000 amperes to the square inch, depending on the size of main and duration of load. Therefore, a 0.5 square inch cable would probably suit the general conditions better, and would be as safe as asbestos in a Turkish bath. This current density bogey of 1000 amperes to the square inch is a relic of the early days when rubber insulation was the only one on the market for power cables.

It is possible that under the following exceptionally adverse circumstances a rubber multiple conductor cable, sheathed with a non-radiating covering, installed in a warm and confined place without ventilation, and run at, say, 1500 amperes to the square inch for a long period of time, might have its in-

sulation injured by the heat generated and retained. This would be quite as serious for plain bitumen insulation; but with modern paper cables danger does not exist even under such exceptional conditions as those mentioned.

The round figure of 1000 amperes taken as a standard is evidence of loose approximation in the rule. So the size may be largely decided by the permissible loss of energy, with little reference to heating effects where paper-insulated cables are used, although with rubber and bitumen-insulated cables more regard must be paid to current density. It should be noted that paper-insulated, bitumen-sheathed cables are on the half-way mark between paper, lead-covered, and bitumen-insulated cables in this respect. The usual calculations will give the most suitable cable section as to loss of energy, but this matter of current density has been thus dwelt upon, as it is very generally misunderstood.

The choice of insulation often depends upon what an engineer has had previous experience with, and upon this basis also largely depend the type of construction and manner of protecting a cable. A man who has used, say, the somewhat old-fashioned system of concentric conductor, paper-insulated, lead-covered cables, drawn into cast-iron pipes for high-tension feeders on alternating currents, with a fair measure of success, will specify the same arrangement for low-tension continuous-current distributors, instead of the most generally accepted arrangement of single-conductor, bitumen-insulated cables laid on the solid system in wood or asphalt troughs. This following of the favourite should be done with more discrimination, if one may express it that way.

The beauties of the mechanically strong paper insulation and waterproof lead sheath are marred in many cases by the secret leak, upon cables which are not scientifically maintained, growing from small begin-

nings, by feeding upon the lead sheath at unknown points, until it reaches the dimensions of a fault. At this stage the trouble is increasing at an alarming ratio, for every ampere that escapes to earth from the surface of the lead is eating a hole in the lead from which new amperes are born to further trouble. Bonding is a remedy, but this, improperly done, is worse than useless, as instead of providing paths of safety, it often opens the gate to trouble. Some engineers prefer to break the lead sheathing up into insulated sections, by using boxes made of glass; and this has many advantages.

Against the decrying of lead-covered cables is the contention that bitumen cables are mechanically weak, that the conductor decentralizes when overheated, and that certain alkalis attack the bitumen.

These allegations are true under certain circumstances, but they are so exceptional that it may be taken for granted that bitumen cables are the most suitable for low-tension single cables laid in troughs, and that for multiple conductor cables, as the three-phase type, paper-insulated, bitumen-sheathed cables are best. For extra high-tension cables it is necessary to have a lead sheath, and, in addition, an armouring of, preferably, galvanized iron wires over the lead, to insure ample conductivity for leakage currents. For mining work bitumen or rubber cables are very useful, as lead sheathing is heavy and easily damaged when hanging down the shafts or in the roads underground, and a fault upon a lead-sheathed cable would shut down a mine without warning, where a similar fault on a leadless cable would give a warning reading upon the switchboard instruments long before it took such a drastic step. And it should be remembered that in mines the conditions are such that faults would sometimes occur if electric cables were constructed of steel conductors, cast-iron-like in-

sulation, and boiler-plate sheathing.

A very frequently omitted precaution with lead-covered cables is the covering with a padding of jute. This jute serving is cheap, and is a most useful protection in a number of ways, and a sound method of insurance against trouble when laying the cable and afterwards. If lead-covered cables had been more generally jute-served they would have created less history.

As to types of construction, the general practice is single cables for direct current, concentric for single-phase alternating current, twin concentric for two-phase, and three-core for three-phase. Where single cables are used for any other type than that mentioned, a loss of efficiency occurs, depending on the sheathing material and other circumstances. The protection of cables for special conditions of use, such as laying directly in the ground, hanging down a pit shaft, running under water, cleating to buildings, mining roads, etc., should be carefully considered. The usual practice for laying direct is to sandwich steel tape between layers of jute, the whole served over the cable itself and well soaked in a tarry preservative. For pit shafts the cable is also jute-served, but the armour is composed of steel wires. The reason for the difference is that the steel tape is supposed to withstand blows from excavating tools better than wire, but as there are no picks at work in pit shafts, the wire is used as being a better support for the cable than the tape. Where rivers or canals have to be crossed, large steel wire is used and ample thickness of tarred jute, to prevent the water from rusting the wires. In mining roads, and particularly in collieries, rubber cables are largely used, with plenty of braiding, to withstand the severe conditions underground.

It should be noted that where armoured cable runs through ground composed of cinders, the sulphur acts upon such armouring very disas-

trously, even though covered with jute. It is best to use another system in such a place, or to specially protect the armour from corrosion. Although occasionally the design of a cable has been the cause of trouble, and occasionally also careless manufacture has been to blame, the chief culprit in a faulty main system is the man who laid it down, or the one who works upon it.

It may be more straightforward to start from the testing of a cable at the factory, where the usual 24-hour immersion test is carried out and the inspector makes sure the insulation reading is up to the mark. If this is upon a lead-covered cable and the test is at all low, it is safest to order another 24-hour immersion and another test after that. If this is not done, there is the possibility of buying a cable with a pinhole or other flaw in the lead, too slight to show a wholly bad test, but bad enough to let one down in a few months' time, the period depending upon the situation of the cable, either in a wet pipe or imbedded in bitumen.

A considerable saving of time results if a hydraulic pressure test can be made instead of the 24-hour immersion in an open tank, and this also results in a more positive reading. In the packing of the cable it is an unfortunate habit of cable makers sometimes to leave nails sticking out somewhere about the drum to injure the lead sheathing. On arrival, therefore, as well as during laying, each drum should be inspected for these traps.

The unloading of cable drums is not the simplest thing to do safely. Ignorant people have been known to let a drum run down a plank from a cart or truck upon its middle where cranes are not available, with the result that the cable got flattened where the weight came on it; or drums have simply been dropped off such vehicles with damaging results to both cable and drum. The proper method is to let it run down a

couple of wide planks on its flanges, with a couple of ropes around its body guiding it.

To run out the length of cable, the drum should be mounted upon proper drum jacks, and the spindle should be fitted with collars to prevent the flanges jamming against the jacks when revolving. If this is not done, the drum will suddenly stop revolving when perhaps there is a big strain on the cable, and then something has to go,—usually the cable sheathing.

A further cause of faults is encountered when drawing cable into a pipe. The proper way is to mount the drum above the pipe entering the drawpit and let the cable be pulled in in the form of a *C*. This keeps it to the same curve as that encircling the drum and allows the drum attendant to keep plenty of slack behind the dangerous edge of the pipe. But when the cable drum is mounted on the far side of the pit the cable must change its curve to an *S*-shape, and much more handling is required to prevent abrasion.

Trouble is very general at the ends of cables. Cables are generally cut several times in a drum length and left to be jointed. If the ends are not carefully covered so as to be waterproof, the result is that they get damp, moisture runs up the interstices of the strand and a length of cable is damaged, according to the class of insulation and the period of time during which it is left in this way. In many cases of failure the cause has been that it was not convenient for a jointer to come and plumb the ends, and so insulating tape was used instead. Such tape may be of use for a short time, but it is a question of time only for moisture to either penetrate it or to creep under it in damp situations. A useful and apparently little known method of making a plumbed end without a blowlamp or metal pot is to "draw" the lead up from about 6 inches along the cable, either by

mere strength of hand or by tapping with a soft wood beater. This gradually produces a lead cylinder projecting from the cable end, and when this spare lead is sufficient it should be tapped over to meet, and then by continued tapping, welded till no joint or pinhole is visible. The writer has proved the efficiency of this by practical experience, but it needs carefulness and some dexterity to be right every time.

In handling cables, they should be treated with the exaggerated reverence usually vouchsafed to infernal machines. There are many ways of damaging them, by impact, by abrasion, or by excessive bending. Most firms of cable makers are apprised almost every week of a new method of disastrous undoing invented by the devils of carelessness, ignorance, or accident. As a general thing, until the cause of trouble is brought home to the right quarter, the impression on the part of the persons inconvenienced by such occurrences is that the cable itself, or its maker, is to blame. The most dangerous time in the life of a cable is during the period dating from its being unwound from its drum until it is completely installed and jointed. When running it out in lengths the really critical time is encountered, as loops are apt to be made in it, and unless a loop is carefully unbent, a kink results, and a kink upon most cables is deadly when forcibly straightened out.

When cables are being laid solid in troughs the chance of damage is greatest when the workman ventures in the trench to haul them along or perchance to fit them into the troughs. The cable may rest on a sharp stone or on the edge of a stoneware trough; the ironshod heel descends upon its one-tenth-inch of lead covering and one-tenth-inch of paper. One-fifth inch of boiler plate might withstand the impact, but little else; and unless this gash is seen before being buried in bitumen, there will be a resurrection day for that

cable. Some firms of cable-laying contractors clothe their employees' feet in felt overshoes where this danger is likely, but this is not always done. A sharp eye and a hard tongue are the chief preventives of such accidents.

With bitumen-insulated cables the same chance of damage is likely, added to which is the method of straightening out cables when in the trough, with picks and crowbars as levers; and the pouring-in of bitumen at an excessive temperature is very trying to bitumen insulation. The decentralization bogey is probably due more to these methods of laying than to the usually accepted reason as to "overloading." Sometimes, because of kinks made in handling, the cable will not lie down, and lengths of a foot or so bulge slightly above the level of the bitumen despite illegal pressure with pickshaft heads, etc. In such a case the sides of the trough should be raised either by nailing boards to them or by bricking them up, so that the height of the compound may be increased to completely cover the protuberant cable.

Regarding the compound used for trough filling, expert opinions differ as to the representative merits of bitumen and pitch compound. Bitumen is usually specified as "best refined Trinidad bitumen," and is more costly than pitch compound, which is a mixture of pitch with a tempering oil, such as resin, or creosote up to 5 per cent. by weight of the pitch. Properly mixed, there is little or no difference in practical value for the purpose of surrounding cables with a permanent waterproof compound; but when the pitch is brittle there is the chance of it cracking if the ground settles. Bitumen is a good all-round material for cable work, and its waterproof, insulating, flexible qualities are taken advantage of by the manufacture of a solid system, composed of bitumen asphalt trough, bitumen filling, and asphaltic-concrete cover, the whole welding to-

gether homogeneously from one end of the line to the other.

Solid systems are usually composed of a trough of one material, like wood or stoneware, the cover being of another material, such as brick or tile, and it is not always easy to ensure that the covers are not knocked off when replacing the earth filling.

When the cable is laid, it has to be jointed up from end to end, and this is the work of skilled men. Joints are more frequently made on cables drawn into pipes than on cables laid solid or direct; and this is one argument against the draw-in system, as joints are the weak spots upon a cable. For instance, a 0.5 square inch cable may be sent in drum lengths of 500 yards, and this can all be laid (in cases where there is a straightforward run) without cutting it, by mounting the drum on wheels and running it along the side of the trench, or by threading the cable under obstructions, such as pipes, and hauling it along the trench by men at intervals. But if the cable has to be laid in ducts, the utmost length that can safely be drawn in is 200 yards, and if there are bends in the run, this may have to be reduced to as short a length as 50 yards, making from two to nine joints more than the solid or direct-laid systems.

There are a number of ways of jointing cables, as there are numerous types of cables. The most usual with single conductors is to thread a copper sleeve over the two conductors, to put a joint box over and fill it up with an insulating and waterproof compound. This method is simple in operation and quickly executed, but it has the disadvantage of leaving the two metals (cast iron and lead) in more or less bad contact, so that leakage currents passing over the lead spark to the box, and in time eat through the lead and ruin the cable. Bonding a copper wire over the box from lead to lead helps to prevent this, but this is not al-

ways done, and even where it is, the passage of a heavy leakage current along the lead would cause a proportionate amount of shunt current to spark across the contact of the two metals. Where wood bushes are used to prevent such action, the period of prevention would only be until the bushes become damp enough to conduct the current. Cast-iron boxes, however, are in very general use, and they do not fail often, but this is in many cases only a matter of time.

Lead sleeves are coming into very general use, and these require a more skillful joiner than is required with boxes. The conductor joint is made in the usual manner, but this is generally wrapped in insulating tape, the sleeve is slipped over and wiped on at both ends like a plumber's water-pipe joint. A hole is sometimes left in the top of the sleeve to be filled in with oil or compound, and then plumbed over. This form of joint, properly made, is well-nigh perfect. It gives ample conductivity to leakage currents, takes up little space, and is solidly homogeneous. It must be made certain, however, that the plumbing is good, and that the metal used is the right mixture, or water will get through the pores inside the joint. To prevent likelihood of this, it is usual to enclose the lead sleeves themselves in cast-iron boxes or wooden troughs filled with bitumen, when such joints are made upon extra high-tension cables. With joints upon bitumen cables it is usual to use bitumen or guttaroid tapes wrapped round and vulcanized, and protected by canvas tapes impregnated with waterproof compound. These joints, being smaller in diameter, are generally left inside the trough and surrounded with compound. Sometimes joint boxes are used on bitumen cables when these are drawn in, as such a taped joint is not safe in wet manholes.

Where branches run off the main cable, a disconnecting box is often used, so that the cables may be di-

vided into sections for testing and in case of faults. This is a cast-iron box, with part of the cable fittings above the surface of the compound which covers the cable ends. Links or fuses are connected to join one cable to another. Such a box should have plenty of room inside, as there have been many accidents through using such boxes in which the dimensions of fittings and clearances between live parts have been made as small as possible for the sake of compactness. If water gets inside these boxes there is trouble, due to it forming leakage paths between the live parts and the box. To obviate this the cover should always be fitted with a broad gasket of good rubber, and the cover should have a deep rim cast around it and should dip into a trough of oil encircling the box. Further, in such a case the inside of the box should be thickly coated with asphalt or enamelled, and the fittings should be surrounded by porcelain, or immersed in oil. Such boxes should be periodically inspected, as while being of considerable use at times, they are weak points on the cables.

The ends of the cables, where connected to switchboards or direct to motors, etc., should be dealt with according to their kind. Single rubber or bitumen cables can be very easily finished off in dry situations by means of rubber and protective tapes, varnished over all.

Multiple conductor cables should

end in dividing boxes near the switchboard, and fireproof rubber tails should be brought from them up to the terminals. As to the maintenance of cables, the character of this largely depends upon the way they have been made and laid, as well as upon local conditions. For instance, cables laid solid under the pasture lands of an estate should not require any attention after being tested every week for three months to make sure that nothing had happened during laying operations. But cables cleated to the timberings of a colliery require daily testing for the rest of their natural lives, for no one knows what may happen to them at any moment. In the generality of cases, however, a weekly test should be made of the whole installation with all lamps, etc., switched off, and if this shows lower readings, the reason for it should be discovered by further testing. Repairs should be executed immediately, remembering that a stitch in time saves nine.

In conclusion, it is well to note that makers of cables who are also contractors for laying them are usually the best people to obtain practical information from in case of trouble, real or anticipated. Also, where practicable, it is best to allow them to lay their own cables, and to make them guarantee the satisfactory behaviour of the cables for a year after laying, which is usually ample time to detect flaws.



THE INDUSTRIAL AND COMMERCIAL POSSIBILITIES OF RUSSIA

By Robert J. Gross

IT has been said of Russia, not only by Americans who have traveled through the domains of that great empire, but by Russian travelers within American borders as well, that in the matter of natural wealth and resource the two countries have much in common. Both embrace vast areas of land, abounding in almost limitless stores of mineral deposit, and in both the national welfare is based upon the cultivation of the soil and the manufacture of its products into the varied and complex utilities essential to the progressive age in which we live.

In Russia, however, as in America immediately preceding the Civil War in the sixties, the chief support of the people is agriculture. According to statistics recently published, a hundred million out of one hundred and forty million population cultivate some three hundred million acres. About two and one-half times this area in European-Russia alone is still covered with virgin forest and immense stretches of swamp. The reduction of these forests to wood and lumber and the reclamation of the swamplands by proper drainage would give Russia this side the Caucasus, nearly one billion acres of tillable land. With her present limited extent of arable territory and the very primitive methods employed, European-Russia now annually produces:—

Wheat	419,000,000 bushels
Rye.....	802,000,000 "
Oats.....	800,000,000 "
Barley.....	252,000,000 "

Had there prevailed an aggressive, intensive and organized agricultural system, there can be no doubt that these figures would have been greatly

increased. Even within the limits of the present acreage, the average harvest returns are much lower than those of other producing nations, as will be seen from the following comparison, given in terms of Russian poods (equivalent to 40 pounds avoirdupois) from one dessyatin of land (equivalent to 37 acres):—

Country	Wheat	Rye	Oats
Russia	28.2	32.8	39.0
United States.....	60.3	40.0	63.1
Canada.....	62.3	62.0	97.7
Germany.....	77.0	56.4	73.9
Sweden.....	100.2	75.9	83.2

The Russian Caucasus and Turkestan, like the American Southern States, abound in large cotton fields which yield annually 800 million pounds of cotton. On the Bessarabian tobacco plantations bordering the Black Sea, nearly one hundred million pounds of tobacco are grown each year. The annual yield of the Caucasian oil fields amounts to about 16 billion pounds of crude petroleum, of which about one-half is consumed in Russia as fuel for locomotives, steamships, iron and steel works, and other industrial institutions. Thousands of acres of valuable mining country lie unexplored and undeveloped, awaiting the strong arm and the enterprising spirit of the pioneer to yield their rich deposits of gold, silver, iron, copper, platinum, zinc, etc. In the Donetz basin, in the southeast of Russia in the Ural Mountains, in Finland, in Poland, and in Central Russia around Moscow, large deposits of coal and iron are found. The Nierchinsk and Baikal Mountain regions also abound in iron ore and coal.

The few demonstrable facts thus far cited certainly show that Russia

possesses those fundamental physical conditions most essential to the up-building of an industrial nation, namely, an abundance of fuel,—both coal and oil,—and large deposits of commercial ores. Notwithstanding these advantages, the manufacturing and industrial affairs of the empire have made little progress and are even more undeveloped than are its agricultural conditions.

Until 1820 Russia imported practically every manufactured product. The needs of her people were few and insignificant. The peasant spun and wove his own clothes and made with his own hands the crude furniture for his poor and unsightly "Eezba" (peasant's house). During the long winter months, he and his family, and indeed the entire village commune, were engaged in making various household utensils carved from wood with rude instruments, painted in gay colours and sold at the annual fairs held in the springtime all over Russia. Until the end of the last century, this industry, known as the "Koustarni Promisle," was the most important existent in the empire and is to-day in many of the central provinces.

Peter the Great was the first of the Russian rulers to recognize the importance of an adequate development of the natural resources of the empire, and it was he who laid, early in the eighteenth century, the foundations of the industrial system which now exists. He sent to Great Britain, Holland, and Germany for artisans and mechanics, and offered them every inducement to settle in Russia, granting them land and privileges as a stimulus to the building up of cities and the establishment of factories and workshops. After his death, however, the home industries made little advancement, and this continued until the last quarter of the nineteenth century when a high protective tariff was levied on all manufactured products imported into Russia, and immediately the establishment of factories was pushed "à outrance" by the

government. This reached its climax under the Witte administration, as will be seen from the following figures:—

During the period extending from 1878 to 1887, the average yearly growth of manufactures under a nominal protective tariff was 26 million roubles; from 1888 to 1892, 41 million roubles; and in the five years from 1893 to 1897, the average annual increase amounted to 161 million roubles, or four times that of the preceding decade. This phenomenal growth was accomplished first by placing a prohibitive tariff on all foreign manufactures and then by enlisting foreign capital to finance the more important industrial projects. This greatly stimulated the establishment and growth of home industries, and for the first time Russia found herself entitled to rank as a manufacturing nation.

The following table gives the yearly supply of foreign capital used in industrial undertakings during a period of fifty years:—

1851-1888 (average)	1,561,000 roubles
1889-1894 "	5,306,000 "
1895	21,070,000 "
1896	52,490,000 "
1897	39,726,000 "
1898	99,770,000 "
1899	93,391,000 "

These statistics show that the aggregate (91,154,000 roubles) of foreign capital employed during the 44 years from 1851 to 1894, was less than the amount in any single year subsequent to 1897. Had the building up of an industrial system excited local competition, and thereby cheapened the home product to a degree corresponding with the imported article; or had the large profits made at first been allowed to remain in the country to swell the wealth of the people, the above figures would convey the picture of a natural and healthy industrial growth. But, unfortunately, such was not the case. The newly established industries, launched and fostered under the auspices of a paternal government, did not result in a cheapening of the product, but, on the contrary, the

high selling price of all protected commodities was rigidly maintained regardless of the manufacturing cost.

It is estimated, for instance, that to the consumer the cost of cotton fabrics amounted to some 123 million roubles yearly over and above what they would have cost without a tariff. As a result, the Russian people were forced indirectly to pay this enormous sum, which went either to swell the dividends of the foreign capitalist, or to purchase favours of special privileges. This applies with equal force to all other lines of manufacture and is to be greatly deplored.

In many of these respects the policy of Russian statesmanship differs quite radically from that of the United States as it existed in the first half of the eighteenth century. From the time of Alexander Hamilton, the father of protection, the American government has favoured a high protective tariff, but, at the same time, has recognized the interests of the farmer,—the most important wealth producer of the country,—as equally if not more important. In evidence of this, attention may be called to the educational opportunities offered in the State Colleges and Universities of Agriculture,—to the gratuitous dissemination of the results of the scientific experiments carried on in the laboratories of the Department of Agriculture at Washington, which enables the American farmer to produce the maximum per unit of soil,—to the extensive irrigation systems built at government expense, whereby millions of acres of arid land have been rendered cultivable,—all resulting in the encouragement and stimulation of a strong personal initiative among the agricultural classes, making their condition far and away superior to that which obtains in any other portion of the world.

It is through this policy also that American industries have reached world-wide prominence and have enabled the United States to become the leading export nation of the world, and not, as is often assumed,

because of the protective tariff alone. In Russia, the policy of the government has always led in an opposite direction, with the result that her industries have been protected at the expense of her decadent agricultural interests, educational advantages have been exceedingly limited, and stimulus to personal initiative has been lacking, due to the paternal character of the government, all preventing a free and spontaneous development of the latent possibilities of the nation.

The same holds true with regard to the railways, which under government ownership have suffered for the past twenty years an annual deficit amounting to about fifteen million dollars. Assuming the truth of the parallel we have drawn as to the physical characteristics of the two countries and eliminating the racial differences, it would seem that those who direct affairs in Russia might find in the history of the industrial development of the United States a solution of many of the problems which now confront them.

A study of the statistics of United States exports during the past century reveals the interesting fact that until 1860, practically all the exports consisted of raw products of the soil, and that during the same period manufactured goods, including machinery, agricultural implements, etc., formed the bulk of the imports. The duties on these imports were not so high as to prevent the pioneer American manufacturer from competing with the foreign-made article, and, as a consequence, the new industries were permitted to thrive and develop on their own merits, and this enabled the American people to obtain implements and household and farm utensils of the best quality at the minimum cost. The demand for the domestic article increased as the wealth or purchasing power of the farmer increased, and this in a large measure laid the foundation of that great industrial growth which has made America first in rank among

the manufacturing nations of the world.

It may not be amiss here to outline briefly a few figures relating to the exports of the United States. In 1860 we note for the first time an appreciable export of manufactures, amounting in all to \$40,000,000,—something less than 20 per cent. of the total exports. Since that time the export of manufactured goods has constantly increased and at a much greater ratio. The following figures show the export of manufactured articles for various periods during the past thirty years:—

1873	\$88,789,758
1880	102,856,015
1890	151,102,376
1891	277,285,391
1902	403,890,763
1904	500,000,000

These statistics demonstrate that American industrial products have now a leading place in the world, and this has been achieved, not through paternalism or by the favouring help of subsidies and bounties, or even by a protective tariff, but rather through measures which have excited keen competition at home and through conditions which have resulted in the increased purchasing power of its individual citizens.

The events of the past half-year, and particularly the trend of the deliberations of the Duma,—the late Russian Parliament,—have shown beyond doubt that the gravest question that confronts that country is a satisfactory solution of the great peasant problem. Should the present government fulfill its promises

and reconvoke the Duma, its first efforts should be directed toward the amelioration of the existing peasant conditions, and to increase in some intelligent manner the purchasing power of the individual.

It is a foregone conclusion that industries cannot thrive in Russia until there is a natural home market for their products, and such market can be created only by solving the land problem in such a manner as to assure an increase in the productivity of the soil. This problem is a very complex one, and under the most favouring circumstances will require a generation at least in which to elevate and educate the peasants and augment their husbandries to the average of their German neighbours.

The removal of the prohibitive tariff in Russia on imported manufactured commodities would tend to cheapen them, and this, of itself, would be a great help to a poverty-stricken people and would also give a much-needed impetus to the Russian manufacturer, and create a healthy competition. It would result in a triple benefit,—to the people, who would be able to buy necessities cheaper; to the government, which would no longer be called upon for subsidies, bounties, and gratuities with which to keep alive bankrupt and decaying industries; and to the manufacturers, who, once aroused from their lethargic sleep, would awaken to the immense commercial and industrial opportunities lying within the borders of their own great Empire.



WIRE ROPE TRAMWAY ENGINEERING

By S. S. Webber



FIG. 1.—AN UNDERHUNG CARRIER IN A DOUBLE-ROPE SYSTEM, WITH THE TRACTION ROPE UNDERNEATH THE TRACK CABLE

THE transportation of materials used in the manufacturing industries, as well as commodities directly consumed in their natural condition, is an ever-increasing problem, while railways and steamships have accomplished wonders in developing commerce and the interchange of products, yet in many parts of the world, especially in the mountainous regions, where most of the mines are situated from which we obtain coal, iron, copper, silver and gold, natural difficulties are found which no railway, as ordinarily constructed, can entirely overcome, and in many places the topography of the country is such as to entirely prevent construction of surface lines. Hence it has been left for the designers and builders

of what are popularly known as wire rope tramways, or aerial tramways, to work out the engineering problems and construct the special types of conveyors suited to these natural conditions, where only an approximate conformation to the surface contours need be followed, and by erecting supporting structures for the cables at favourable elevated points, the intervening ground, be it a ravine, or valley with a river flowing through it, can be crossed in a single long span, thus eliminating the building of bridges, trestles, and other costly structures.

A further advantage in the construction of wire rope tramways lies in the fact that in many situations the coal and ores, as taken from a mine, are delivered to the tramway at an elevation considerably above the point where the tramway will discharge its burden; hence the force of gravitation, due to the descending load, is utilized to run the tramway and bring the empty carriers up the grade, to be again loaded, making its action continuous. In many cases the power so developed is more than sufficient to make the tramway self-operating, and the surplus can be utilized to run machinery for crushing ore, compressing air, or to assist in running the mill machinery, suitable mechanism being employed to make the required power connection at one or both terminals.

Wire rope tramways may be classed under two heads,—the single-rope and the double-rope system. The single-rope system has one rope spliced endless, carried on grooved sheaves, which revolve on axles mounted horizontally in bearings set on the tops of supporting towers,

which may be of timber or metal, the rope at the terminals passing around grooved sheaves of large size, usually 6 feet to 8 feet in diameter. The carriers, with the attached buckets for holding the material to be transported, are suspended from this endless moving rope and travel with it, the loading and unloading of the buckets taking place at the terminals. In this system, the moving rope carries the weight and fixes the rate of movement of the loaded carriers and likewise of the empty carriers returning on the opposite side, the rate of speed being controlled at the terminal stations, either by an engine or electric motor, if a power-driven line, or by powerful band brakes attached to the large sheaves, or other means of absorbing or transmitting the surplus power, if operated by gravity. The capacity, both as to individual loads in each carrier (about 150 pounds) and the speed of movement (about 250 feet per minute), being limited under this system, it is employed only for small daily tonnages, from 50 to 150 tons being the usual quantity, and is found in use at small mines,—those under development, and where first cost is a prime factor.

The double-rope system has the endless moving rope the same as the single-rope system, with the addition of a separate pair of parallel cables, usually termed track cables, upon which the loads are sustained. These cables are supported on iron saddles grooved in their upper surface, the saddles resting on the

tops of supporting towers. The carriers, which are attached to the moving endless rope, termed the traction rope, are provided with two-wheel trolleys or carriages which run on the track cables. The latter are of larger diameter than the endless traction rope, and are not made with a view of flexibility, being drawn quite taut by having one end anchored firmly and the other drawn up by a large screw connection, or, as is most usual, by attaching a very heavy weight,—from 5 to 25 tons,—according to the size of the cable, this weight being so suspended over a sheave as to keep a constant tension on the cable, regardless of variations in length due to stretch, or to expansion or contraction due to changes in temperature, or to variations in loading.

By this method individual loads

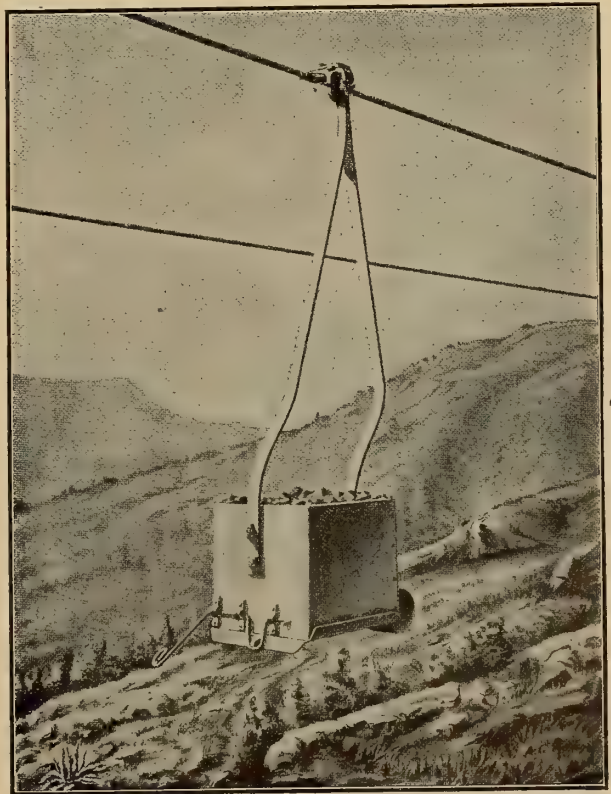


FIG 2.—A SINGLE-ROPE TRAMWAY

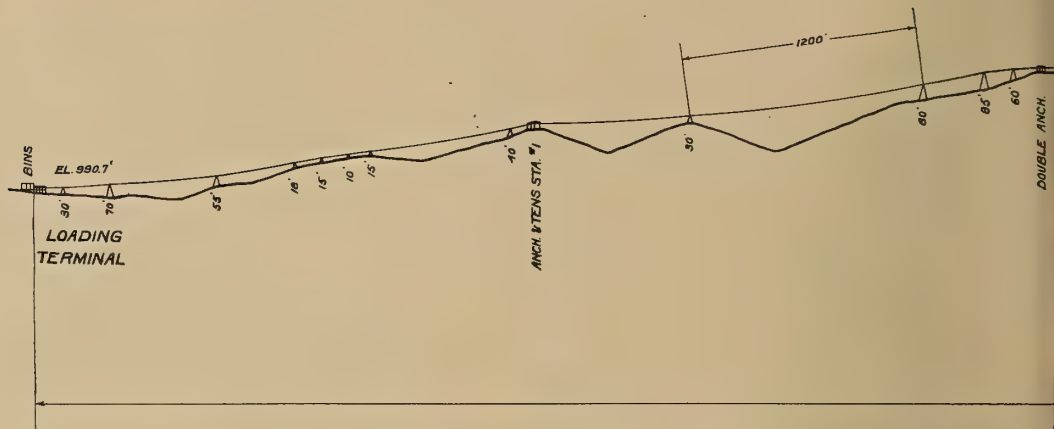


FIG. 3.—TYPICAL PROFILE OF A BLEICHERT WIRE ROPE TRAMWAY. THIS PARTICULAR ONE WAS INSTALLED FOR THE

up to one ton, or even more in special cases, may be carried, and the rate of movement of the carriers along the track cables can be increased two to three times over that attained in the single-rope system; hence the daily tonnage or capacity is much greater in the double-rope system, daily tonnages (ten

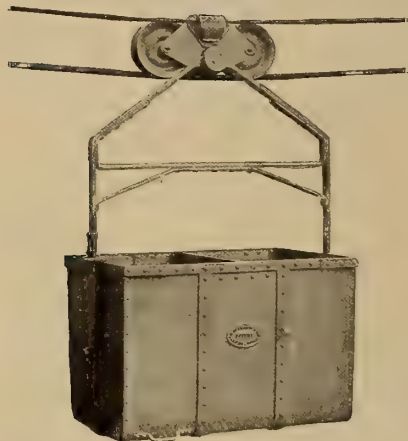


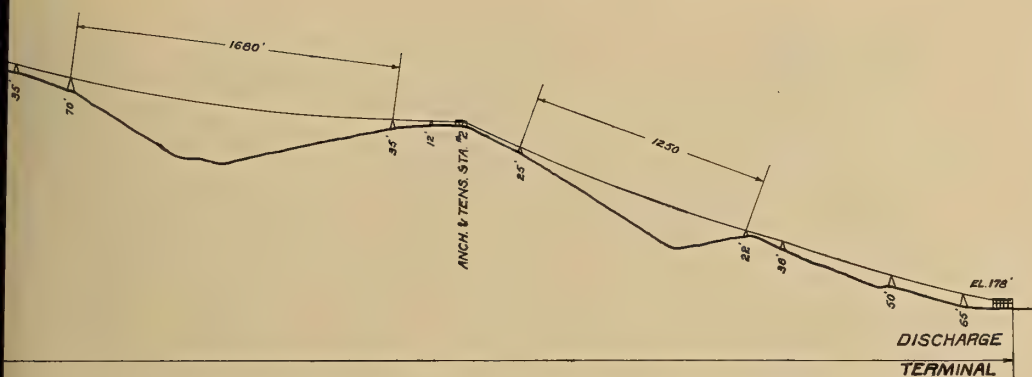
FIG. 4.—AN OVERHUNG CARRIER. THE TRACTION ROPE HERE IS ABOVE THE TRACK CABLE

hours) of 2000 net tons being about the maximum, though in special instances, where the grades were favourable, greater tonnages have been carried.

The moving or traction rope is usually placed below the track or carrying cables and parallel with

them, but some lines have been built with the traction or running rope a few inches above and slightly at one side of the track cables. This arrangement gives an opportunity to so set the sheaves at stations where a change in the direction of the line is desired, termed angle stations, so that the carriers can pass around the rim of the large sheave wheel without detaching from the traction rope, both going and coming. This is of great advantage in some situations, as with the traction rope hung below the track cables, a curve or angle can be passed only in one direction, as the hanger or bail by which the bucket is suspended interferes with the rim of the sheave in the other. Fig. 4 of the accompanying illustrations shows a carrier with overhung traction rope adapted to pass around angles in the line; Fig. 5 shows the underhung rope with grip set below the carriage; Fig. 7 shows an angle station combined with a rising grade on one side, a loaded carrier going up on one cable and an empty coming down on the other.

At the terminal stations are placed the large sheaves around which the traction rope runs, the mechanism for gripping and ungripping the carriers as they enter and leave the station, and the switch rails on which the carriers run to reach the points



UNITED STATES MINING CO., AT BINGHAM, UTAH, U. S. A., BY THE TRENTON IRON CO., OF TRENTON, NEW JERSEY

of loading and discharge. The carriages, on reaching a terminal or intermediate station, leave the suspended track cables and enter on fixed bar rails, these having tapered ends and fitting closely to the upper surface of the cables so as to allow the carrier wheels to pass from one to the other without shock or jar.

As the carriers enter a station where it is desired to stop to load or unload, they engage with an automatic attacher, which unlocks the grip securing the carrier to the moving traction rope, and at the same point where the detaching occurs either the track rail or the traction rope is deflected sufficiently to cause the carrier to swerve away and clear the traction rope. The momentum of the detached carrier will be sufficient to cause it to run on the rail for some distance, if so desired, so that the points for dumping or for empty carriers,—the loading bins,—are reached without any hand pushing, carriers often running in this way around curves or over switches from 50 to 100 feet, thus allowing loading or discharge from or into one or more bins that may be arranged in different locations in the terminal structure (see Figs. 10 and 11).

The general arrangement of terminal rails is in the form of a loop, the discharging of the carriers tak-

ing place on the entering side, or at the end of the loop, the empty carriers passing to the opposite side for the return trip. When it is desired to send either a loaded or an empty carrier out on the tramway line, all that the operator or attendant has to do is to push the



FIG. 5.—A BLEICHERT AUTOMATIC GRIP FOR AN UNDERHUNG TRACTION ROPE

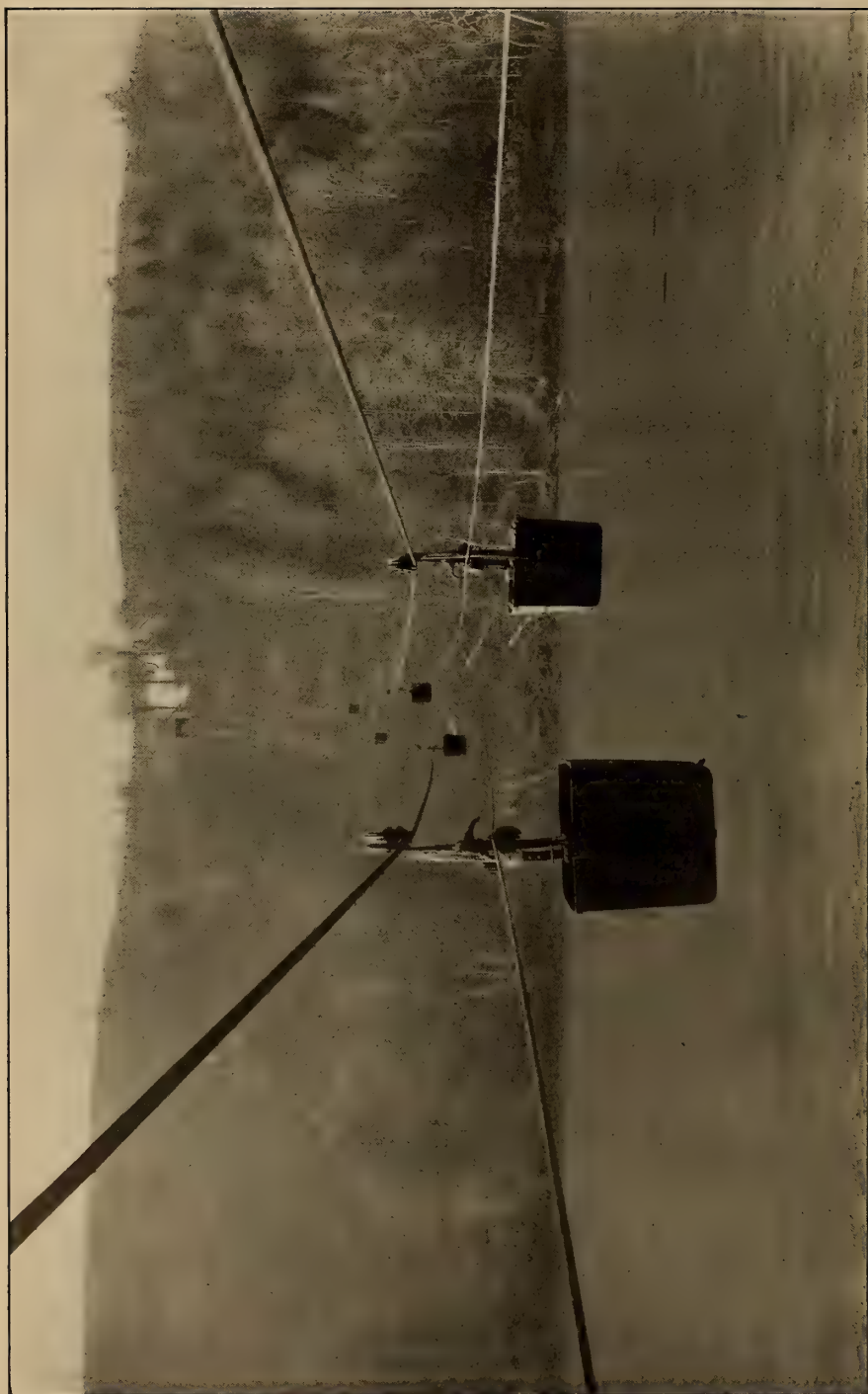


FIG. 6.—UNDERHUNG CARRIERS, WITH GRIPS SET BELOW THE CARRIAGES. THIS VIEW SHOWS A BLEICHERT TRAMWAY BUILT FOR THE KEYSTONE COAL MINING COMPANY, AT EAST BRADY, PA., BY THE TRENTON IRON CO., TRENTON, NEW JERSEY, U. S. A.

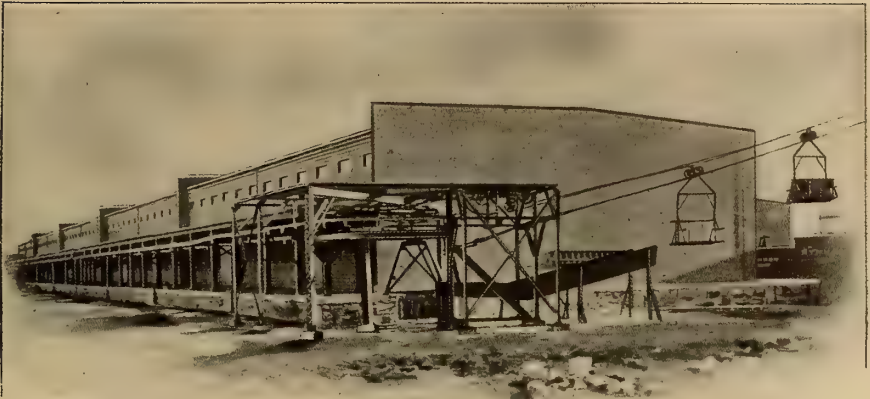


FIG. 7.—A DOUBLE-ROPE SYSTEM WITH A RIGHT-ANGLE TURN AT THE WORKS OF THE PLYMOUTH, MASS., CORDAGE CO., ERECTED BY THE TRENTON IRON COMPANY, TRENTON, N. J., U. S. A.

carrier a few feet along the overhead rail, the traction rope being guided to such a position with respect to the track cable as to enter the open jaw of the grip, which, by the action of the automatic attacher, quickly closes down on the rope as the carrier continues its forward movement and thus passes out of the terminal under complete control of the traction rope.

With this brief description of the method of sending out and receiving the carriers, both loaded and empty, we will pass to a consideration of some typical tramway lines in actual service, taking as an example one of the most remarkable lines yet built, being the longest line in existence.

This tramway was designed, built, and installed by the firm of Adolf Bleichert & Co., Leipzig-Gohlis, Germany, for the Government of the Argentine Republic, in South America, under the direction of the Secretary of the Department of Public Works, and was constructed for the purpose of conveying the ores from the mining district of "La Mejicana" to the railway station at Chilecito. The total length is about 22 miles, and the difference in levels between the terminals is about 11,500 feet. The elevation of the loading station

is over 15,100 feet above sea level, the power station is about 14,300 feet, and the discharge station at Chilecito 3610 feet, giving a fall of 11,490 feet. The capacity of the line is 40 tons of ore an hour, requiring the despatch of eighty buckets or carriers hourly, each holding half a ton, or at intervals of one every 45 seconds, corresponding to a spacing of 370 feet. The line is divided into eight sections, and is provided with brakes and hydraulic governors for controlling the surplus power developed on some sections, and steam engines are employed to supply power for operating the others. About four hours are required to make a trip over the line.

Another tramway of more than usual interest is one built by the Trenton Iron Company, of Trenton, N. J., U. S. A., on the Bleichert system, for the Compagnie Haitienne for transporting logwood from the forests in the Island of Hayti, West Indies, to the shipping port of Port de Paix, a distance of over twelve miles. The line crosses several streams, and some trouble was experienced during construction and the first year of operation due to the sudden floods and changing of the bed of these streams at points where



FIG. 8.—DUMP PILE, TIPPING FRAME AND BUCKET DISCHARGING LOAD. AN EMPTY BUCKET IS RETURNING ON THE OPPOSITE CABLE. TRAMWAY OF THE COLORADO FUEL & IRON CO., AT SOPRIS, COLORADO

the supporting towers of the tramway were set too close to the bank. The result was that two towers were undermined by the current and new foundations of greater depth and strength were required in place of the original ones. In one case a support had to be moved several yards to get on safe ground.

The tramway has been in service several years, and has proved very

satisfactory to the owners. The logwood is cut into lengths of from 2 to 4 feet and loaded into carrier frames to an extent of about 300 pounds to each, the carriers being sent out at intervals of 54 seconds. On arriving at the terminus at Port de Paix, the logwood is dumped from the carriers onto a large pile, from which it is transferred to lighters and taken out to the vessels,

which, owing to the lack of sufficient depth of water, cannot lie close in shore to permit of loading at a wharf, though at some future time a dock will probably be built and the tramway terminal brought out onto the wharf. The loading will then be done directly into the hold of the vessel.

At Isham, Tenn., U. S. A., a Trenton-Bleichert tramway has been in operation for about a year, conveying coal over a distance of four miles from mines owned and operated by J. V. Le Moynes, the line being designed to convey 500 tons of soft coal daily (ten hours) from the mines to the railroad. As the mines are situated in a valley with a ridge intervening between it and the railroad, the application of about 75 H. P. is required to drive the

tramway when running at full capacity. The buckets, 122 in number, are designed to hold 1250 pounds of coal each, and are loaded and sent out at intervals of 45 seconds, running at a speed of 500 feet per minute.

The loads are carried on a "locked-wire" cable of $1\frac{3}{8}$ -inch diameter, the empties returning on a cable 1 inch in diameter. The traction rope is $\frac{3}{4}$ inch, carried on steel rollers over the supports at an elevation slightly above the track cables, the supports being seventy-four in number and ranging from 15 feet to 65 feet in height. The grips are of the automatic type, the gripping pressure being applied by the weight of the bucket, hence the more load there is in the bucket, the more firmly the traction rope is gripped.

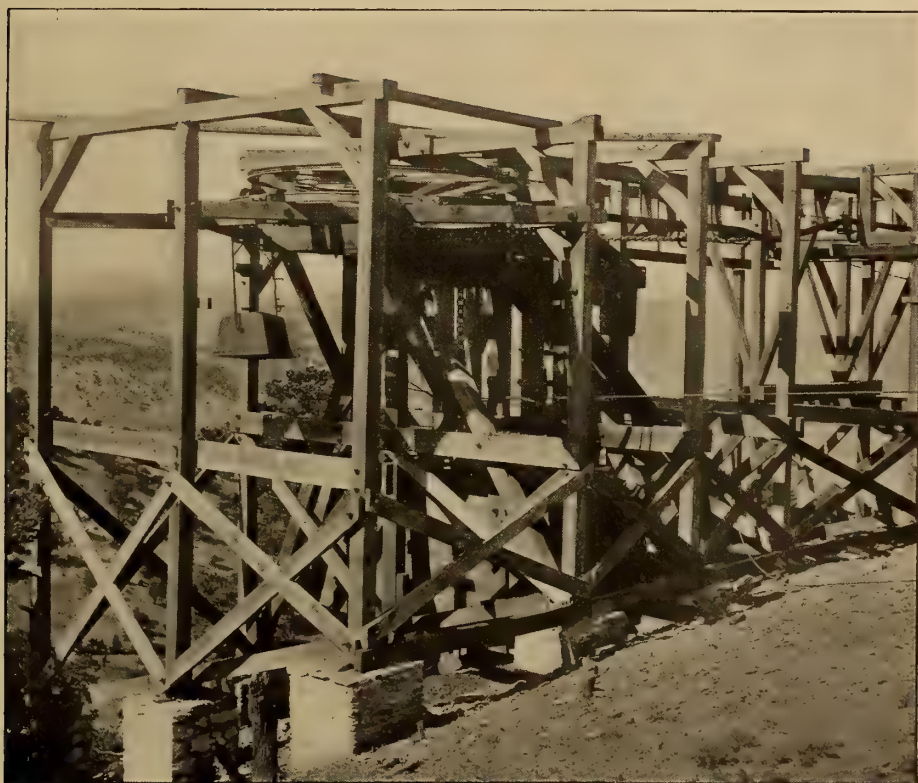


FIG. 9.—A TERMINAL, SHOWING AN EMPTY BUCKET PASSING AROUND A TERMINAL SHEAVE ON A CURVED RAIL



FIG. 10.—VIEW OF A WEBBER COMPRESSION GRIP AND AUTOMATIC ATTACHER, SHOWING THE CARRIER PASSING THROUGH BEING GRIPPED TO THE TRACTION ROPE



FIG. 11.—A TERMINAL STATION, SHOWING ONE OF THE AUTOMATIC ATTACHERS FOR THE CARRIERS.
A LARGER VIEW OF THIS ATTACHER APPEARS OPPOSITE

The arrangements for detaching and attaching at the terminals are entirely automatic, thus reducing the operating expenses to a small item for labour.

Another notable example of successful aerial tramway construction is the Trenton-Bleichert line built for carrying ore from the Highland Boy mine to the railroad at Bingham Cañon, Utah, U. S. A., owned by the Utah Consolidated Mining Company. This was built in 1899. It is 12,700 feet long, with a descent of 1150 feet between loading and discharge terminals. The line runs by gravity. The descending loads, besides hauling the empty buckets back for reloading, develop about 25 surplus H. P., which is, in part, utilized in carrying coal and mine supplies up to the mine by partly loading the otherwise empty buckets. The cost of moving a ton of ore a distance of two and a half miles is about seven cents. The daily (ten hours) tonnage is about 400 tons. This tramway has been in constant operation for over seven years,

with a fine record for operating expenses and maintenance.

Another Trenton-Bleichert tramway at Bingham, Utah, was put in operation in 1902, for the United States Mining Company, to bring down the copper ore from the mines owned and operated by that company to the railway terminal. This tramway has a length of 11,124 feet, with a difference in level of 812 feet, although the contour of the ground is such that the loads go up-grade from the loading terminal, making an ascent of 600 feet in the first 5200 feet to the summit. From there the line runs on a down-grade, falling 1412 feet in the remaining 5924 feet, so that the total fall of 812 feet enables the line to be run by gravity. The daily (ten hours) tonnage is 500 tons or more, and about 20 surplus H. P. are developed, which are controlled and absorbed by a hydraulic controller or regulator of a special pattern built by the Trenton Iron Company.

The carrying or track cables are of the "locked-wire" type, $1\frac{3}{8}$ inches



FIG. 12.—AN INTERMEDIATE SUPPORT AND DUMP FILE, WITH LOADING TERMINAL AND WORKS IN THE DISTANCE, AND BUCKET SHOWN AFTER DUMPING.
THE COLORADO FUEL & IRON COMPANY'S PLANT AT SOPRIS, COLORADO, U. S. A.

in diameter for the loaded carriers and 1 inch for the empties, although coal, mine supplies, tools, and other small freight are daily carried up the line in the returning buckets. The traction rope is $\frac{7}{8}$ inch diameter. The carriers or buckets are 103 in number, and each holds 1200 pounds of ore when loaded, moving at a speed of 333 feet per minute. They are spaced 240 feet apart, corresponding to a time interval of 43 seconds.

The intermediate supports are twenty-four in number, varying in height from 12 to 95 feet. There are three intermediate tension and anchor stations, where the main track cables are anchored or weighted to maintain a uniform tension under all conditions of loading and temperature. The longest span is 1675 feet between supports, with two others of about 1200 feet, and several shorter spans from 400 to 700 feet in the clear. While no tonnage costs are at hand for operating this line, it may be fairly assumed to be not over 6 cents per ton per mile, and if only the wages paid while running are considered the cost per ton per mile would be less, no account being taken of the returning up-freight, which, on the assumed cost for the ore coming down, is carried free of cost.

A wire-rope tramway erected for the Colorado Fuel & Iron Company at their coke plant at Sopris, Col., is an instance where the buckets carrying mine refuse to the dumping ground, some 2000 feet from the breaker, automatically discharge their contents and pass around the sheave and rail at the outer terminal, returning to the loading point without attention. Illustrations reproduced from photographs show the automatic dumping, and the passage of empty buckets, bottom upwards, making the turn at the terminal. See Figs. 8, 9 and 12. The dumping or tripping frame may be shifted along the cable as the refuse pile accumulates, thus making a continuous

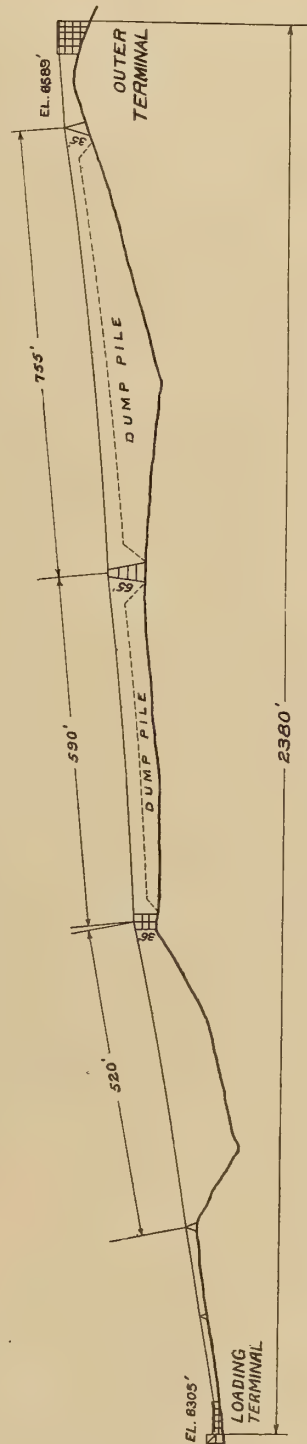


FIG. 13.—PROFILE OF THE BLEICHERT TRAMWAY OF THE COLORADO FUEL & IRON CO. AT SOPRIS, COLORADO



FIG. 14.—A WIRE ROPE TRAMWAY FOR HANDLING COAL AT THE TRENTON IRON COMPANY'S WORKS
TRENTON, N. J., U. S. A.

pile or embankment along the line of the tramway, which provides for the disposal of many thousands of tons of waste rock.

The cost of transporting a ton of waste so disposed of will be quite small, two men at the loading terminal, filling buckets from bin by means of a cut-off gate and chute operated by hand wheel and gear, at the rate of one bucket, holding 1400 pounds, every two minutes, which includes the time for righting and latching the empty buckets as they come into the station, and pushing the loaded buckets into the mechanical attacher, this being all the labour employed in operating. About 10 H. P. are required to drive the tramway, and, reckoning this at \$300 per horse-power per annum, or \$1 per day, and adding the wages of two men, with oil and small incidentals, we have a total of \$8 per day. Dividing this by the daily tonnage carried,—200 tons,—makes the cost of disposing of the refuse rock and dirt 4 cents per ton. Should the daily tonnage be increased, as it may be by putting more buckets on the cables and shortening the

time interval, the cost per ton would be reduced as no more labour would be required. This tramway has been in service for more than a year with satisfactory results.

As an instance of a light capacity tramway of low first cost and low cost for operating, Fig. 14 shows a tramway at the works of the Trenton Iron Company for conveying coal from a bin under a railway trestle to the boiler house, about 700 feet distant, the tramway crossing the roofs of two factory buildings and a main street 60 feet wide at an elevation of 30 feet above the street level. The discharge terminal is on the roof of the boiler house, the coal being delivered into bunkers from which the coal feeds to the automatic stokers by gravity. This tramway requires two men to operate it, one at each end to attend to filling and dumping the buckets, which hold 250 pounds of coal. About eighty buckets an hour are the regular rate of running, and for the quantity of coal used at boilers each day an hour and a half of tramway operation suffices, the operators being yard labourers, who begin

work each day on the tramway for the time mentioned. The power required is about 4 H. P., furnished by an electric motor at the boiler house end. The wages paid are 50 cents for the time that the line is in use, and adding for power, oil, etc., 10 cents, makes 60 cents for conveying 30 tons of coal, or 2 cents per ton, from railway cars to bunkers.

Before putting in the tramway the coal was hand-shoveled into cars on surface track and hauled by electric locomotive to boiler house, where it was dumped on the floor, at a cost of about 10 cents per ton, making a saving of 8 cents per ton to the credit of the wire rope tramway, which, on 30 tons, is \$2.40 per day, or \$720 per year. This will not only pay for the tramway in four years, but will pay the interest and repairs, and were the quantity of coal handled larger, the saving would be proportionately greater.

Data respecting cost of repairs and renewals on wire rope tramways are not as available and complete as might be desired. Some companies keep an accurate repair account, and have given the cost per ton. This, together with the writer's knowledge of the value of the renewal and repair parts ordered from the makers by the different companies operating the tramways, will enable a fairly close estimate of renewal costs to be made. For the first two or three years the repairs are only such as may be caused by accidents due to storms, snowslides, fires at mills or breakers, destroying the terminal stations. These are, fortunately, of rare occurrence, though the money loss in such instances is often quite considerable.

After three years' operation, the repairs to portions of the track cables, carrier wheels, axles and gripping mechanism began to show to a slight extent,—about 2 per cent. per year on the cost of the tramway, and often less, assuming the average cost of the tramway at \$10,000 per

mile and an average tonnage of 60,000 tons per year. This percentage of renewals and repairs comes to about one-third of a cent per ton per mile.

After five years the repairs and renewals outside of serious accidents, will keep quite close to 5 per cent. per year on the cost of the tramway, or, say, eight-tenths of a cent per ton per mile, and adding this to the



FIG. 15.—ANOTHER VIEW OF A DOUBLE-ROPE PLANT AT BINGHAM, UTAH

wages for operating, which may vary from 3 cents to 6 cents per ton per mile, we have a total charge of 3.8 cents to 6.8 cents per ton per mile.

That there are some exceptions to this is, of course, true. The writer knows of instances where, with very light tonnages and extended terminals requiring a movement of the carriers over a more or less complicated sys-

tem of rails with switches, turntables, elevators, etc., necessitating the employment of more labour than usual, the cost has reached twenty cents per ton; but, on the other hand, where the tonnage is heavy (from 1000 to 2000 tons per day), the cost of transporting a ton per mile on long lines will not exceed 1 cent. The writer has before him letters received from various mine managers and superintendents of plants

operating tramways which fully bear out the statements of cost as given.

The use of wire rope tramways is steadily on the increase, as their constructive and economic advantages become better known, and the fact that nearly, if not quite, two thousand lines have been built, most of them yet in service and showing good results, gives them a place for which it will be difficult to find a substitute.

MODERN MACHINE SHOP REQUIREMENTS

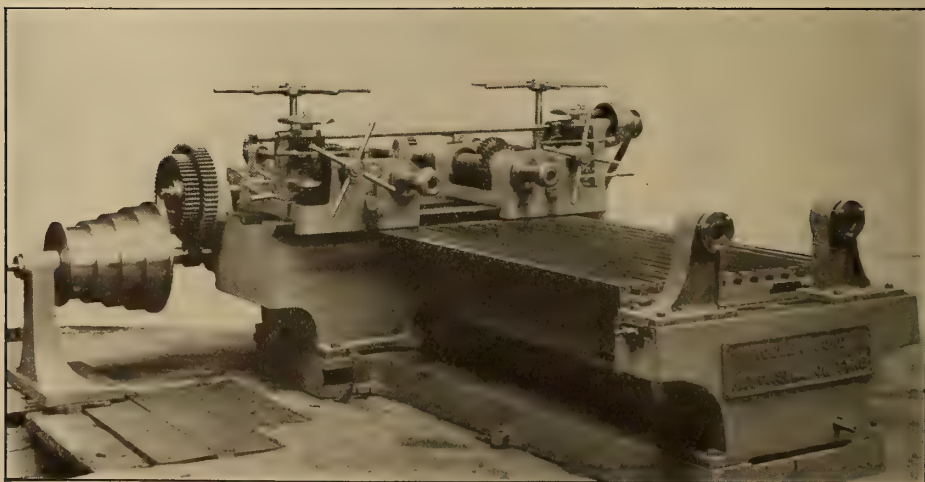
AIDS TO RAPID AND ECONOMICAL OUTPUT

By Joseph Horner

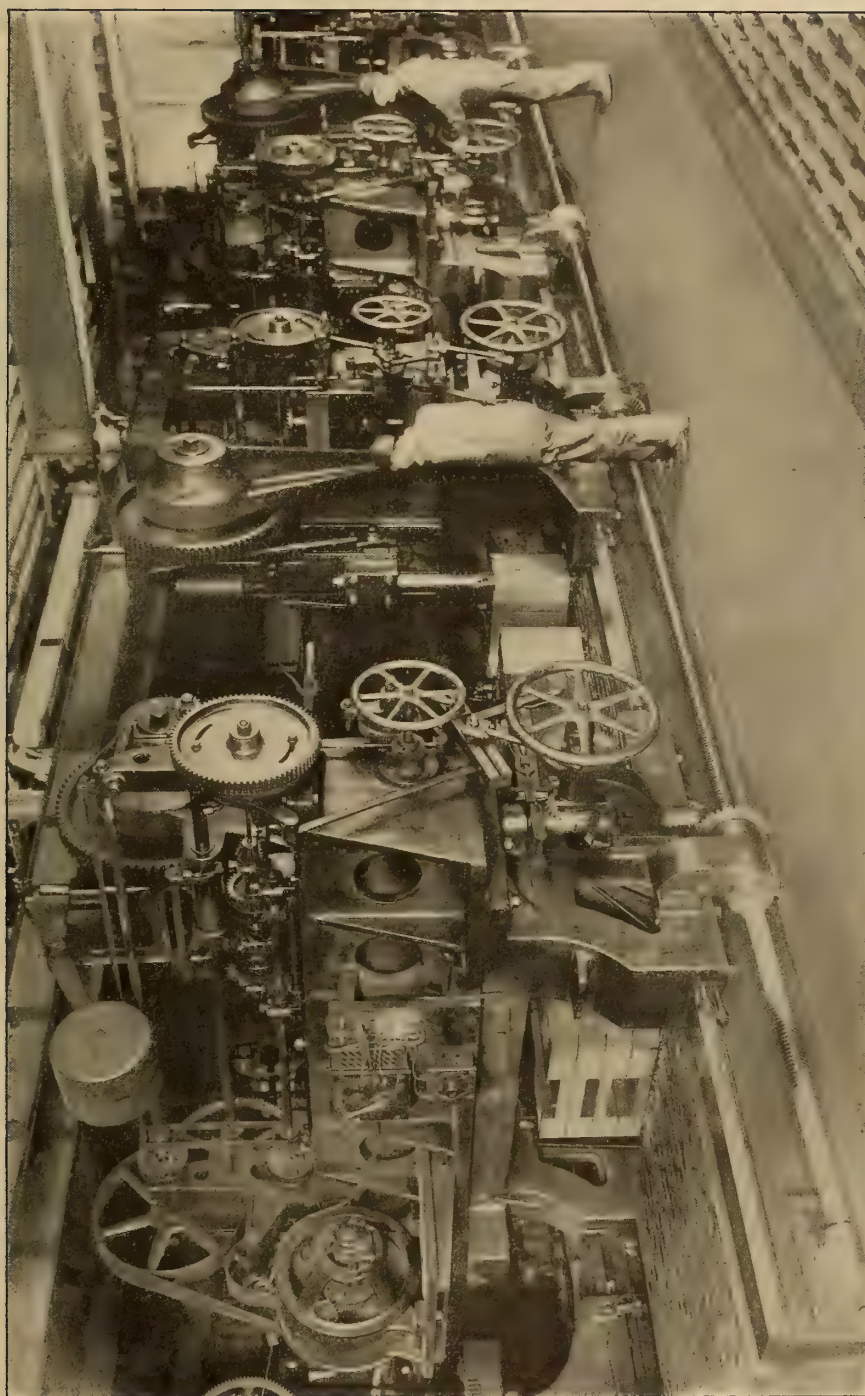
MACHINE SHOP managers cherish their ideals, as do other men. Many and great have been the innovations of recent years. But the larger number of machine shops still may be classed as average. There are only a few first-class shops which come up to the ideals of a man imbued with a sense of good system and perfect

correlation of means to ends, though the number is rapidly increasing.

The chief causes of the changes which have come into shop methods have been the perfecting of old types of machines, the evolution of modified and improved types, the introduction of machines and power processes in place of hand operations, the growth of special manufacturers,



DUPLEX HORIZONTAL DRILLING AND BORING MACHINE FOR CRANK WEBS, PISTON AND CONNECTING-RODS, ETC. BUILT BY MESSRS. NOBLE & LUND, LTD., NEWCASTLE-ON-TYNE ENGLAND



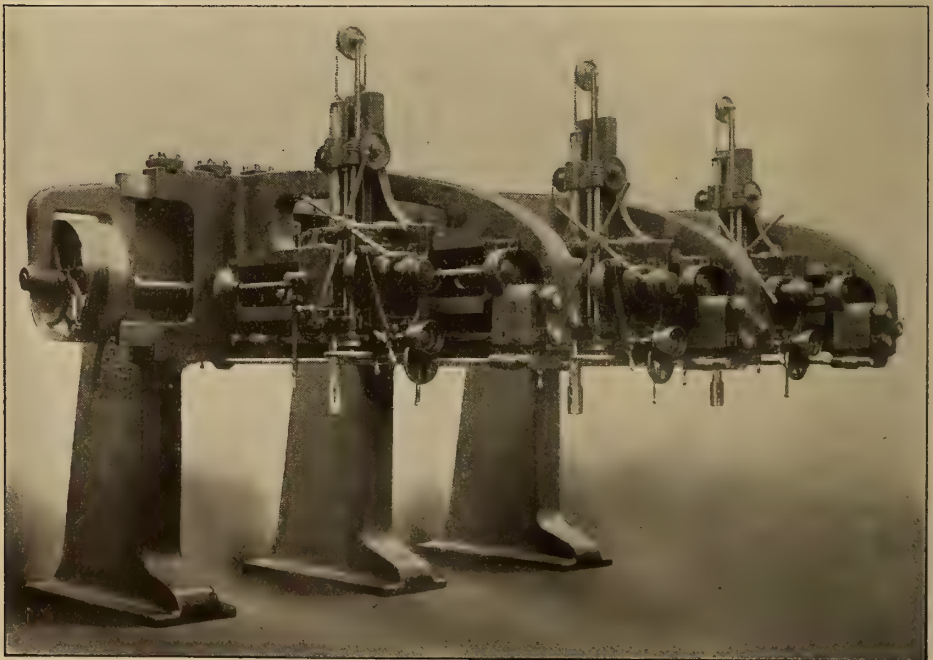
SLOTING TWO SETS OF FOUR LOCOMOTIVE FRAMES EACH AT THE BALDWIN LOCOMOTIVE WORKS PHILADELPHIA, PA

better arrangements of shops and factories, and the growth of big factories. But in the adoption of improvements it is necessary for a firm to hasten slowly. Some have burnt their fingers in the too eager quest after the ideal. Too much has been sunk in building, in new machines, in elaborate clerical systems,—more than the volume of business has warranted. Still the movement is one that is bound to go on, and firms who do not recognize the need for growth must lose status at last.

Heads of firms sometimes act as though they believed that the purchase of the best modern machinery is sufficient to insure a perfect machine shop; but such is not the fact. There is only one aspect of paramount importance in the factory, namely, the economical, and this is the point of view to be taken. Mere ingenuity in design, beautiful mechanical movements, patented devices, all these are wholly subordinate to the question of profit and loss, with

which are closely identified accuracy and excellence of the work turned out, or the reverse. Machines are bought and operated with a view to profit, to competitive manufacture. If they fulfill these conditions, they are successful; if they do not, they spell loss to their possessors.

In many shops there is a want of elasticity in the methods of doing work. It is curious how conservative most men are when the question of tooling arises. Because a certain kind of article has been sent to the planing machine regularly in the past, it must be so treated still. It seems like an act of sacrilege to deprive the planer of its work, even though a milling machine may be capable of doing it quicker and perhaps just as accurately. All sorts of objections are made to the proposed change. The work will not be done so accurately, or the milling cutters will give trouble, or the surface will be left with chatter marks, or be untrue, or the planer hand will



THREE-SPINDLE DRILLING MACHINE FOR TUBE PLATES AND GIRDER WORK. BUILT BY MESSRS. NOBLE & LUND, LTD., NEWCASTLE-ON-TYNE, ENGLAND



ELECTRICALLY DRIVEN GRINDERS IN THE SHOP OF THE GENERAL ELECTRIC CO., AT SCHENECTADY, NEW YORK. THE EMERY WHEELS ARE MOUNTED DIRECTLY ON THE MOTOR SHAFTS

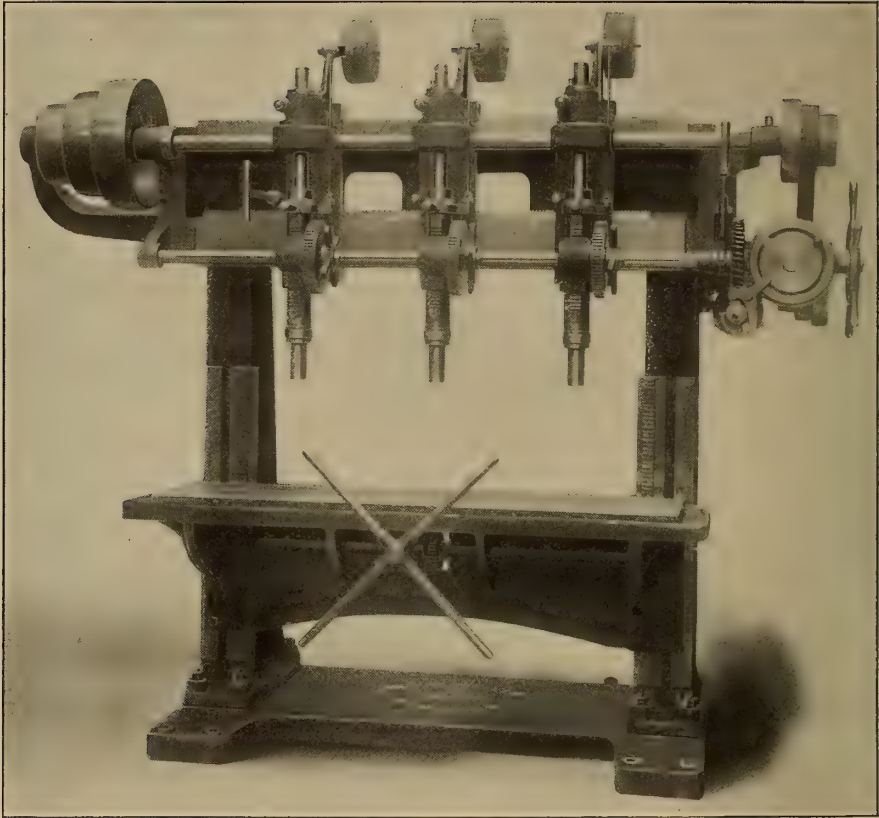
take offense if his craft is invaded, and so on.

The same kind of thing occurs if lathe work, sanctioned by long use and wont, is sent to the grinder, or to the milling machine; or if the work of the slotter is sent to be milled, or, in fact, if any changes are made in methods which have been followed for many years.

It is possible to offer some slight justification for this attitude. Men feel secure in following routine work. If innovations are to be made, it rarely happens that either workmen or foremen will initiate them. Responsibility lies heavily on their shoulders, and the advantages to be

derived from improvements do not accrue to them, but to the principals, while blame for failure is awarded to them. And they are not encouraged to devise improved methods, the case of a very few establishments excepted. And so they get into a perfectly explicable attitude of mental inertia, inconsistent with the ready adoption of elasticity in methods of doing work.

Yet if the management could but regard the work of the machine shop from a new standpoint, what beneficial economical results might follow. Results should be studied in relation to machine methods, and not conversely, as is now often the case.



THREE-SPINDLE DRILLING MACHINE, BUILT BY MESSRS. JAMES ARCHDALE & CO., LTD.,
BIRMINGHAM ENGLAND

If an object is to have a flat surface, that is no reason why it should go to the rectilinear machines using single-edged cutting tools. Such surfaces can be produced in machines using rotary cutters, or on grinders, and in each type numerous varieties are available. The circular table of the slotting machine type is equally available on the miller, or on the grinder. Holes may be made on many machines, as in lathes, both horizontal and vertical, in boring mills, on numerous kinds of drilling machines, with vertical and horizontal spindles, and in the grinder. The machine that affords the best facilities and the highest economies is the one to be selected.

Sometimes the best results may be obtained by dividing the work be-

tween two machines, sometimes by doing it all at one setting on one machine, and there are many cases in which each of these devices is contrary to the hard-and-fast methods in the average shops.

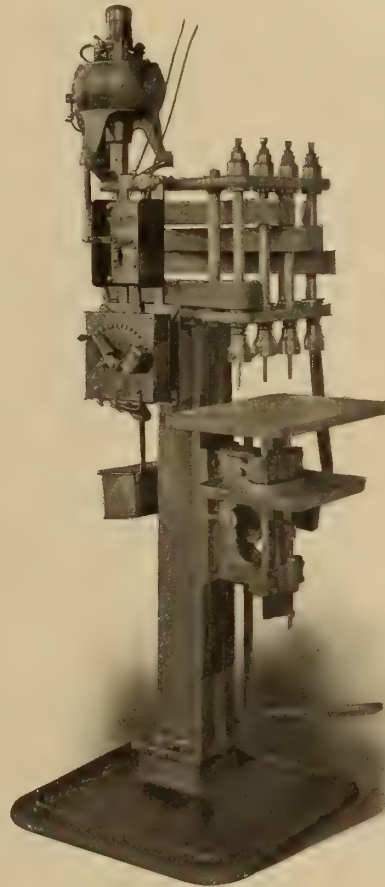
At the present time more than in the past, the two classes of shops,—those in which specialities alone are handled and those where articles of a miscellaneous class are produced,—become more sharply differentiated. The first stands for the modern, the second for the older system. Besides these there is an intermediate class in which numerous specialities are dealt with in distinct departments, controlled in all respects as though they were distinct establishments, save for the central authority which is exercised.

One of the most important results of growing specialization is that almost the whole machine practice of a generation past has been profoundly changed or modified. Thus, for example, much work that was formerly done on lathes is now performed elsewhere on special machines derived from the lathe, such as automatic and semi-automatic turret lathes, and screw machines. The milling machine, again, has appropriated much that formerly went to the planer, the shaper, or the slotter. The boring machine has invaded the province of the lathe; the keyway machine that of the slotter; gear cutters have taken work from the milling machine; grinding machines have usurped the functions of lathes, planers, milling machines, and other types.

In each class of tool, again, recent highly specialized forms have each taken something, often a good deal, from the universal or general tools of the same class and name, until we now have gear-cutting machines for dealing with spur wheels only, others for bevels only, or for worms or worm wheels; others for cutting wheels by mathematically true methods; and the same is true in the case of other machine tools. A point to remember is that the methods of the specialized shops are now largely adopted in the general shops.

In considering the question of economy which results from the lessening of labour costs, we see that this reduction results either from increasing the capabilities, capacities, and output of machines, and the substitution of the work of one class of machines for that of another, or from putting more than one machine in charge of an attendant; or, in many instances, in the combination of these economies. In these directions great advances have taken place latterly, and it is certain that we have thus far witnessed only the beginning of growth on these lines.

The capability and capacity of machines is increased in two ways. It is done by increasing their power, so that more material is removed in a given time, that is, by stiffening machine framings, tool holders, and tool boxes, by increasing driving power or speed so that the tool will remove more material, and the machine stand the extra stress, and notably by the use of the high-speed steel



A NEAT ADAPTATION OF VERTICAL MOTOR TO A
FOUR-SPINDLE DRILL

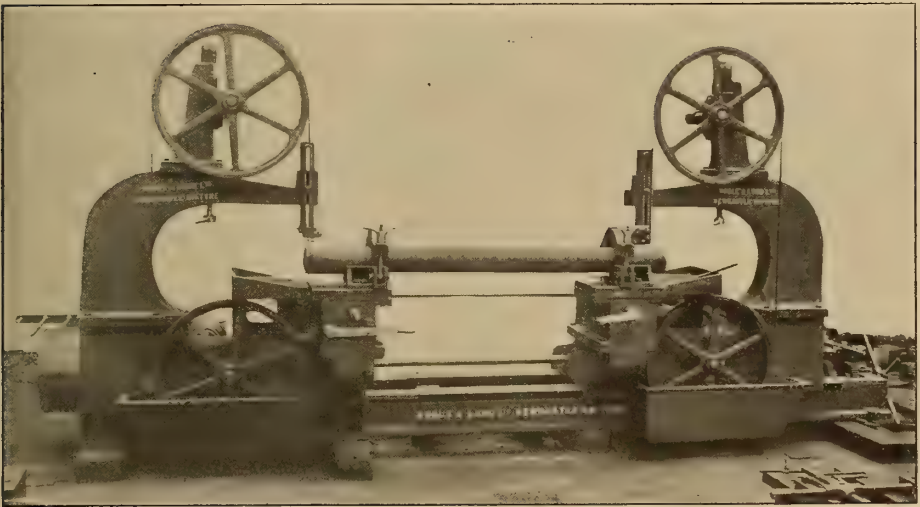
tools, in lathes stiffened up to endure the stress of cutting. Capacity is also increased by multiplying the number of cutting tools, either in simultaneous operation, or in rapid consecutive action. Examples are the duplex lathes, the double tool boxes



THE OVERHEAD TROLLEY SYSTEM FOR CONVEYING MOLTEN METAL IN THE BRASS FOUNDRY OF THE GENERAL ELECTRIC COMPANY, AT SCHENECTADY, NEW YORK

on planing and slotting machines; the employment of two, three, or four tools in separate holders in planing machines,—tooling faces and edges; duplex boring machines going through two cylinders simultaneously; multiple drills, drilling from two to fifty or more holes at once in various types, and many other machines. A particular example of this kind is the milling cutter, which, though a single tool, is an aggregation of many cutting edges, a few of which are operating at the same time, while all cut in quick succes-

ished by employers. The ideal has often failed, because the old standard types of machines generally demand the undivided attention of one man, simply because they require very frequent, though not constant, intervention. But since the automatic and semi-automatic machines have been developed, the ideal is being realized, and one man or lad now often does look after a small group of machines, in some cases half a dozen or more. When increased capacity for work and automatic movements are combined, the highest eco-



DUPLEX BAND SAWING MACHINE FOR CUTTING RAILWAY AXLES TO LENGTH. BUILT BY MESSRS. NOBLE & LUND, LTD., NEWCASTLE-ON-TYNE

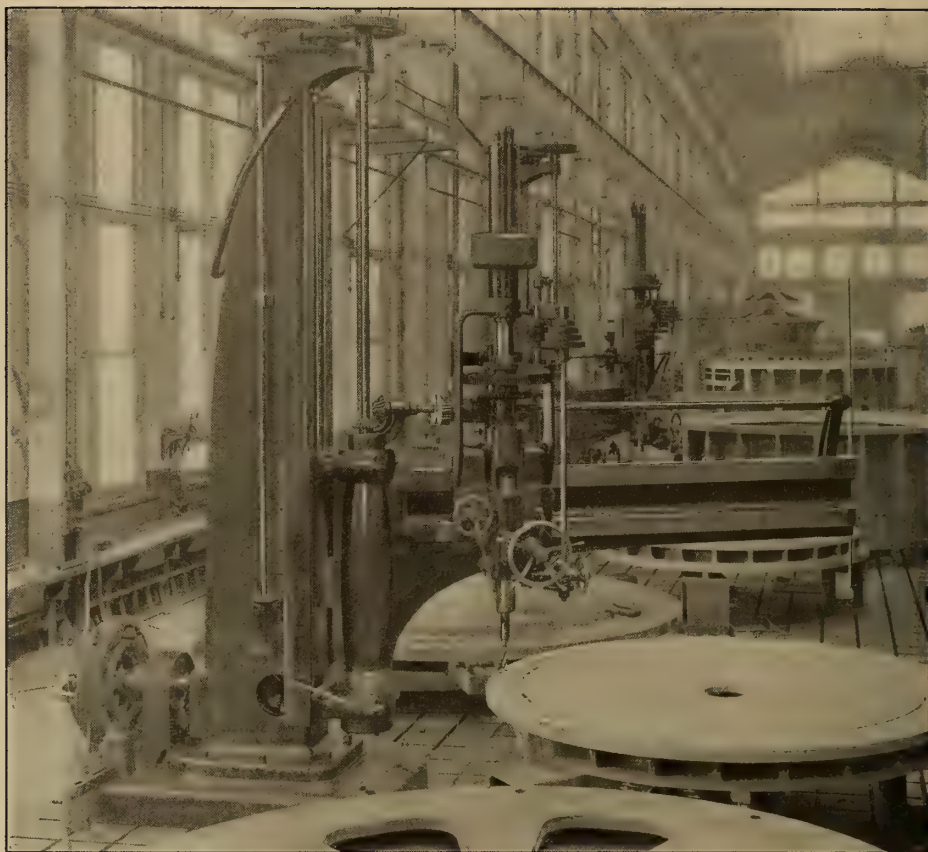
sion without the loss of time inseparable from tools held in reciprocating machines. A more special case is that of emery grinding. Grinding machines now fill a larger place than at any previous period, and grinding is yet full of promise. An emery wheel is a multiplication of cutting points moving over the work at a rate far in excess of the point of any cutting tool, and, therefore, removing metal rapidly.

The second method of lessening cost,—that of putting more than one machine in charge of an attendant,—is an ideal that has long been cher-

ished by employers. The ideal has often failed, because the old standard types of machines generally demand the undivided attention of one man, simply because they require very frequent, though not constant, intervention. But since the automatic and semi-automatic machines have been developed, the ideal is being realized, and one man or lad now often does look after a small group of machines, in some cases half a dozen or more. When increased capacity for work and automatic movements are combined, the highest eco-

nomical developments in reduction of labour costs are secured. An economical practice in which some machine-shops are lacking is keeping all machines occupied to their best possible capacity. It is much more difficult to do this in a shop where a large proportion of jobbing work is done than in those which have a good run of specialities. In the former it often occurs that pieces of work which are not best suited to a machine are put upon it, simply to prevent the machine from lying idle for some hours or days.

A case in point would be allowing



A PORTABLE ELECTRICALLY DRIVEN 12-FOOT RADIAL DRILL IN THE STEAM TURBINE SHOPS OF THE GENERAL ELECTRIC CO., AT SCHENECTADY, NEW YORK THIS ILLUSTRATION SHOWS VERY WELL THE METHOD EMPLOYED IN MAKING THE MOTOR CONNECTION WITH A WALL CUT-IN

boring to be done on a lathe that might be done cheaper on a boring machine; another would be doing some turning on a common lathe that could be better done on a hollow-spindle capstan lathe; another is chucking for boring and turning on a horizontal lathe instead of on a vertical one. But if the more suitable machine is occupied, and will continue to be occupied for a considerable period, and the other has no work upon it, then strict economy must be sacrificed to the lesser economy.

If this sensible view alone were taken, there would be nothing to complain of. The evil lies in foremen not looking ahead and mentally

gauging each man's work sufficiently in advance of its completion. Then, when notified that another job is wanted, there is a scurry to get anything in the machine that is at all suitable for it, though it may be far from being the most economical piece of work that could have been picked out if some forethought had been exercised.

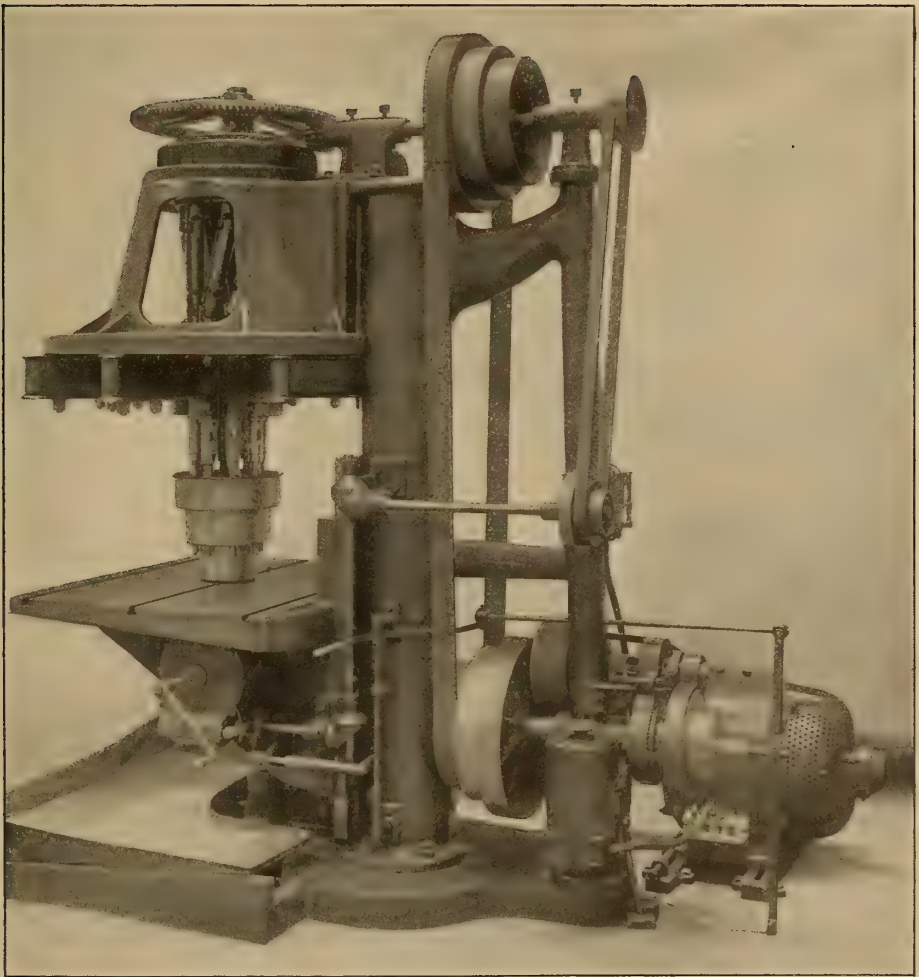
The job which best suits a machine is the one that is done most economically upon it, and which exercises its capacity and power at the maximum. Big work should go to big machines, unless in some instances a large number of smaller pieces all alike can be done simultaneously. Examples of this kind

occur in planing and shaping in series, in slotting in piles, in turning segments on a large face plate, in boring levers or castings in line, and so on,—work which takes less time in proportion to the setting than single pieces would occupy.

A great help to the foreman keeping machines occupied to the best of their capacity is a system of maintaining good stocks. Even in times full up with orders, stock can be often run through by the judicious occupation of machines. There does thus sometimes happen the apparent

incongruity of working on stock while busy with orders. In such cases the stock may cost little, because but for it a machine might be temporarily idle, or, if not idle, at least occupied on unremunerative work.

But in busy times principals often say they cannot do any stock, and when slack they cannot afford it. But if standing orders are kept for sets of stock parts, and a foreman is left to the exercise of his discretion, he will often turn it out for much less than it would cost if



A PRATT & WHITNEY MULTIPLE-SPINDLE DRILL DRIVEN BY A GENERAL ELECTRIC MOTOR. THE COMPACTNESS OF THE CONTROLLING APPARATUS NEAR THE LOWER CONE PULLEY IS VERY CLEARLY SHOWN

done during time when orders were slack. This will be done partly because the machine work can be arranged better, but partly also because when trade is falling off, men get into slack ways and are afraid to finish one job before they see another coming on. In busy times they try to clear off everything quickly. A foreman who understands human nature is well aware of this, though all do not care to say as much.

Another economical matter in which many shops are lacking is a good arrangement of machines. The best arrangement is that of groups, machines of similar character and size being placed in proximity, away from other groups of a different character and size. That, however, is not the system which exists in many shops hampered by want of room for extension. In these the heavier machines generally line a main gangway, and the lighter ones are set behind, a method which provides very well for serving the heavier machines by power. But as time goes on and new machines are introduced, these have to occupy areas that were originally intended to be left clear, or to be occupied with work in progress, and so the result is that the shop becomes crowded with machines and with work. Also machines of different

kinds are laid down in about the same areas, frequently involving unnecessary movements of work, often being in confined positions which makes proper handling of work difficult.

It is not so necessary to locate machines of a class together as it is to keep heavy and light machines in separate areas. But much depends on the kind of work done in a shop. If the separate departments include numerous machines of one class, then they should be kept in groups, as, planers together, lathes of one kind and size, drilling machines, boring machines, etc., each in a group. But in a shop of medium size, and in small shops, the best arrangement is grouping simply into heavy and light machines. A big planer will then be near a big slotter, a big boring machine or a face lathe, and all alike will be served with suitable lifting tackle, so that a job can be passed from one machine to another without having far to travel.

So, too, all the small machines can be located in another portion of the shop, or in a separate building, for the operations to be performed by them are not done on the same parts that are put on the big machines. As they thus have no connection, the machines will not be anywhere near one another.

To be Concluded

MULTIPLEX TELEGRAPHY

AND SIMULTANEOUS TELEGRAPHY AND TELEPHONY

By William Maver, Jr.

THE average layman regards the statement that it is possible to transmit two and even four messages over one telegraph wire at the same time as little short of a miracle. Still, the statement is true, and has been true for over thirty-four years, or since 1872. Prior to that time the possibility of sending two messages at one time over a wire had been mooted, and experiments had been made by Dr. Gintl, an Austrian telegraph director, in 1853, and by Dr. Stark, of Vienna, in 1855, to demonstrate that such a thing was possible, but without practical results.

Indeed, Robert Sabine, in his excellent work on "The Electric Telegraph," published in London in 1867, after describing the proposed systems of Gintl and Stark, closed his description by saying:—"Both of these systems of telegraphing in opposite directions, and of telegraphing in the same direction more than one message at a time, must be looked upon as little more than 'feats of intellectual gymnastics,'—very beautiful in their way, but quite useless in a practical point of view."

It was not more than five or six years after Dr. Sabine had pronounced this dictum on the subject that Mr. J. B. Stearns, of Boston, Mass., invented the duplex system of telegraphy which bears his name, and by means of which two messages are transmitted in two directions simultaneously. Not long thereafter Edison, by combining the systems of his predecessors, invented the quadruplex, by means of which two messages were sent in opposite directions at once, making possible the

transmission of four messages simultaneously over one wire.

Two simple principles are involved in the operation of the quadruplex telegraph,—first, what is termed the increment and decrement of current principle, and, second, the reversal of direction of current principle. The first principle is employed in the Stearns duplex, the second is employed in what has long been termed the polar duplex.

A key, termed a transmitter, is utilized to increase and decrease the strength of current on the line. A pole-changing key is employed to reverse the direction of the current on the line. A relay, termed a neutral relay, responds at the distant end of the line to increase and decrease of current strength on the line, and not to reversals of polarity. An instrument, termed a polarized relay, responds to reversals in direction of the current, but not to increase and decrease of current strength. One operator can thus transmit signals by operating the transmitter, to which signals the neutral relay will respond, while another can transmit signals by operating the pole changer to which signals the polarized relay will respond. These devices, therefore, make it possible to send two messages in one direction on one wire.

In order to be able to transmit two messages in opposite directions on one wire, it is necessary that means be devised for preventing the action of the transmitting keys at one station, *A*, Fig. 1, for instance, from affecting the receiving relays at that station. This is done by winding the relays at each station with two

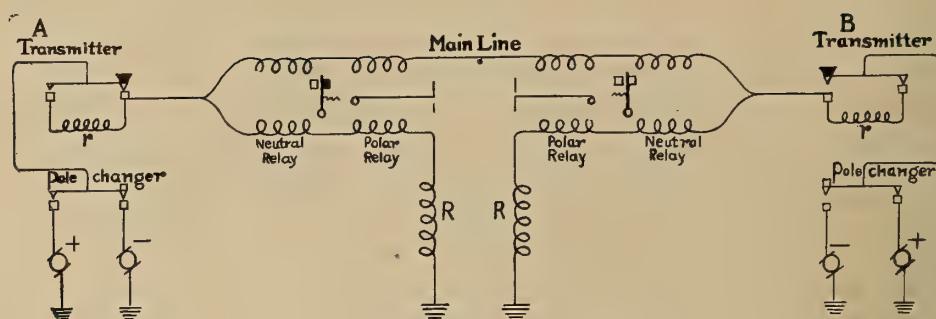


FIG. 1.—DIAGRAM ILLUSTRATING THE PRINCIPLE UNDERLYING MULTIPLEX TELEGRAPHY

coils, through which the current from the near station passes in opposite directions. In addition to this, there is provided what is termed an artificial line (consisting of coils of German silver wire), and which is given an electrical resistance equal to that of the main line. The main line is then connected to one of the coils of the relays, while the artificial line is connected to the other coil of the relays, as shown in the annexed diagram. The result is that when current is sent through these relays from the station in which they are respectively placed a current of equal strength passes through their coils in opposite direction and the cores of the relays are not magnetized. When, however, a current from the distant station arrives at the near station, a current of greater strength passes through the main line coil of the relays than flows through the artificial coils of the same relays, with the result that their armatures are attracted. In this manner the signals of the operator at the sending station do not affect the relay at that station, and vice versa. In the diagram the increase and decrease of current is obtained by cutting in and out the resistance r at the transmitters.

The polar duplex is the duplex system now used almost exclusively both in overland and submarine cable telegraphy. By its use the wire capacity is practically doubled. When it is considered that the cost of a trans-Atlantic cable is approximately

\$5,000,000, the immense value of the duplex system, which, by means of a few pieces of additional apparatus (costing only a few hundred dollars) at each end of the cable, gives the full equivalent of an additional cable, the great value of this invention can be better appreciated. In shop phrase this additional cable is termed a "phantom" cable. While it is, in fact, a "phantom" cable, cable managers and stockholders find it very realistic in its results.

Similarly, the quadruplex system, which is used only on overland circuits, gives the equivalent of four wires, three of which are "phantom" wires, and by its use to-day in this country the telegraph facilities are increased by many thousands of miles of wire.

It may be noted that in submarine duplex telegraphy the action of the transmitter at the near station upon the receiving instruments at that station is prevented by placing the recorder in a "bridge" wire equivalent to that in the Wheatstone bridge. It should also be noted that the artificial line of the submarine cable duplex necessarily approximates much more closely to the actual cable, as regards electrical resistance and capacity, than does the artificial line of overland telegraphy to the actual overland line. In overland telegraphy the necessary capacity is given by attaching one condenser or several to the artificial line. In the case of submarine duplex telegraphy, the artificial cable consists of strips

of tin foil that in resistance and capacity equal that of the actual cable per unit of length.

Duplex and quadruplex telegraphy does not, however, exemplify the limit of ingenuity on the part of telegraph engineers. By a system known as combined telegraphy and telephony, it is quite practicable to operate two duplex telegraph systems on the two wires of an ordinary metallic telephone circuit without disturbing the operation of the telephone circuit. Thus, by the aid of this modern miracle, while one master of industry may be speaking over a long-distance telephone circuit, the telegrams of another master of industry may be passing over the same wires, the one utterly oblivious of the presence of the other.

By the way, it is frequently stated by people who do not know whereof they speak that it is impossible, by any known means, to prevent the "tapping" of telegraph wires, that is, to prevent people so disposed from reading what is passing over a tele-

graph wire. It is, however, well known to expert telegraphers that it is quite impracticable for anyone to read, by tapping the wire, what is passing over a duplex or quadruplex circuit in full operation.

The devices employed to make it possible to carry on telegraphy and telephony on the same circuits sim-

ultaneously are comparatively simple. It is well known that if a telephone receiver be placed in an ordinary telegraph circuit, a loud crackling noise is heard in the receiver, due to the rapid back-and-forth movements of its diaphragm, produced by the opening and closing of the telegraph key. It is evident that these noises in the receiver must be obviated before simultaneous telegraphy and telephony will be possible. This requirement is met by the introduction of self-induction in the circuits, which makes the rise and fall of the telegraph currents so gradual that the diaphragm of the telephone receiver is not inflected to and from its electro-magnet with sufficient rapidity to produce sound. Upon these gradual inflections of the diaphragm the rapid current variations due to the telephone transmitter are superposed.

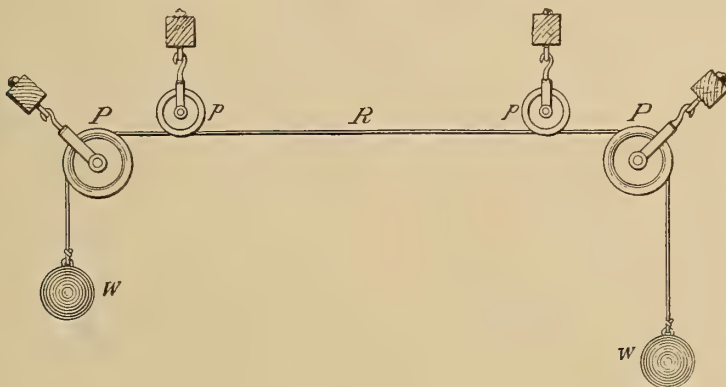


FIG. 2.—A MECHANICAL ILLUSTRATION OF THE PRINCIPLE OF SIMULTANEOUS TELEGRAPHY AND TELEPHONY

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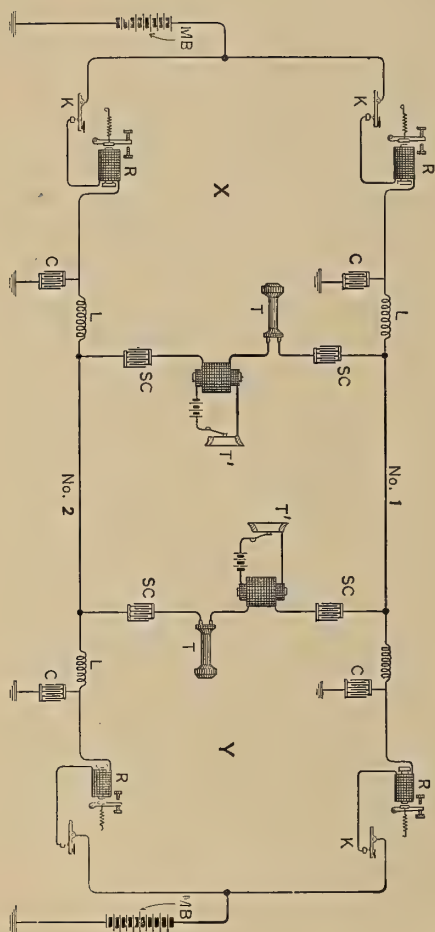


FIG. 3.—SIMULTANEOUS TELEGRAPHY AND TELEPHONY

over the rope, as indicated. When the rope is moved longitudinally, to and fro, one weight will rise while the other will fall, and by a pre-arrangement of the movements of the weight at either end of the rope, signals might be transmitted, during the transmission of which signals the smaller pulleys would be practically at rest.

If, however, while the rope is being moved to and fro, as stated, it be hit with a hammer, it will be set into vibrations that will cause the smaller pulleys to dance while the vibrations continue, but these vibra-

tions will not interfere with the reception of signals by the rise and fall of the weights. If, also, the frequency of the strokes of the hammer upon the rope be pre-arranged, signals due to the "pulsatory" motions of the rope could simultaneously be transmitted.

In Fig. 3 is shown an arrangement of circuits and apparatus for the practical operation of simultaneous telegraphy and telephony. Wires No. 1 and No. 2 represent two telegraph circuits between stations X and Y. The keys *K* and relays *R* of the telegraph circuits are of the usual kind. The telephone instruments are indicated by *T* and *T'*, the receivers and transmitters, respectively. The self-induction required to round out the telegraph currents is supplied by inductance coils *LL*, which consist of soft iron rings, over which the wire is wound. Sufficient inductance is used to produce the desired graduation of the telegraph current, which result is aided by the condensers *CC*.

It will be seen that the telephone system employs a metallic circuit formed of wires No. 1, No. 2, but it is metallically separated from those wires by condensers *SC*. It is also seen that there is no inductance on the wires between the telephone apparatus; hence, the telephone signals are unobstructed between Stations X and Y. While also the condensers *SC* prevent the passage of the telegraph currents from wire to wire, they readily pass the rapidly undulating currents of the telephone system. The current for the telegraph system is supplied by batteries or dynamo machines *MB*.

This combined system of telegraphy and telephony in its original form was due to Mr. Francois Van Rysselberghe, of Belgium. The accompanying figure suffices to illustrate the theory of operation of the system, but some refinements now employed in actual practice are not shown.



Current Topics

AMERICA will, next month, have its first exposition of devices for safeguarding the lives and limbs of workingmen and women, and for preventing accidents under the ordinary conditions of life and labour to which the general public is exposed. The exposition will be held at New York, under the auspices of the American Institute of Social Service, and promises to be of general interest and much practical value. As far back as 1889 there was a German Exposition for the prevention of accidents. In 1893 an exposition of this nature was held in Amsterdam, and since then there have been several similar expositions in Continental Europe and in Canada. As an outgrowth of these national movements several museums of security have been organized, one at Vienna in 1890, one at Amsterdam in 1893, one at Munich in 1900, one at Berlin in 1901, and one at Paris in 1905, and Russia, which we are inclined to look upon as semi-barbarous, within the past year established a museum on a large scale in Moscow. That these expositions and museums have been of real value to their respective countries is evinced by a comparative study of the number of accidents in Europe and in

America, which shows that for the same number of men employed in a given trade the latter has from two to nine times as many accidents as they have in European countries. Such conditions can exist only through general ignorance of their reality, and it is for the purpose of educating the public to an appreciation of the actual situation and the means of its improvement that the exposition of safety devices is to be held. The interest of manufacturers generally is solicited, as well as that of organizations whose special function is to improve the conditions of labour, and a widespread response is looked for to this request for representation in the nature of photographs, descriptive drawings, models, and, as far as possible, the devices themselves in actual operation.

THE selection of the voltage to be used in an electric isolated plant is a matter of considerable importance. Primarily, the cost of wiring is affected by the voltage selected; but this is not the only point at issue. If the plant is equipped with alternating-current motors without exposed contacts, with no commutators to give trouble,

and with well-designed switches, a higher voltage may be safely run than in the case of a direct-current installation. A factory equipped with a 550-volt induction motor is, on the whole, a safer installation, from the standpoint of the employee, than a direct-current plant fitted with 500-volt, direct-current motors on the individual drive basis. Even though a 550-volt alternating current carries with it a maximum of over 800 volts at the peak of the wave, there is more likelihood of trouble from the commutators and exposed contacts so often found in 500-volt, direct-current plants.

WITH the individual direct-current drive,—as in a modern printing press establishment,—it is important that the switches and controllers be installed within the most convenient reach of the operators. In some of the more recent plants of this character it has been necessary to protect these switches by special insulated barriers, and it is difficult to secure all the flexibility desired without introducing the danger of serious shocks to the careless employee. Again, it is a pretty difficult problem to build very small efficient motors for operation on 500-volt circuits, on account of the requirements of insulation. The problem has apparently been solved in some of the later plants, but it is a question if 220 volts are not a better potential for such small work. The current requirements of anything under a 5-H. P., 220-volt motor are not, as a rule, serious enough to make very much difference in the cost of wiring. The labour item will not be radically less with the higher voltage, and it is a question if the total yearly 500-volt motor cost will show economy when fixed charges and operating expenses are carefully added. A single accident to an employee may easily wipe out the difference in first cost of a 500-volt over a 220-volt installation, and while it is

possible to so insulate the 500-volt motor and its controlling switch that no trouble will arise, it is certainly a much simpler matter to use the lower potential in plants where the employee is likely to become careless on account of daily and intimate association with the equipment. It would be unreasonable to decide in favour of the lower potentials in every case, but the matter ought to be well weighed before installing a 500-volt outfit in very small sizes of motors.

NOTWITHSTANDING the very creditable advances that have been made by workers in the wireless telegraph field in improving the sensitiveness and reliability of the receiver of Hertzian waves, it seems evident that we are yet working in a rather roundabout way to obtain the desired result. The present methods, ingenious as they may be, are about as indirect as the existing methods of obtaining electricity from coal. If the electromagnetic theory of light is the true one, then the retina is the most direct and most sensitive of all electric wave detectors. The eye detects the luminiferous electric waves and transmits them to the brain. To utilize the Hertzian waves we have usually to employ some comparatively clumsy mechanical apparatus first to detect and then to convert these waves into sound waves before they become perceptible to our senses. Professor Bose has devised an oscillator capable of setting up vibrations of the order of 50,000,000,000 per second. This, as Professor Bose states, is within thirteen octaves of visible light. These waves are, however, much too short for practical use over long distances in wireless telegraphy.

To obtain visible light, it is necessary that the arriving Hertzian waves at wireless telegraph stations shall be transformed by some means, such

as a frequency changer, into oscillations having the frequency of light waves. We should then see the arriving signals. The nearest approach to a receiver of this kind is, perhaps, the Righi detector. This consists of a tube containing a rarified gas and two electrodes very close together (0.039 inch apart) in circuit with an external battery the electromotive force of which is just a little below that necessary to pass a current. When Hertzian oscillations pass in the circuit the tube is illuminated, and the illumination ceases with the waves. This general principle, it may be noted, is also used in electric wave meters by Slaby and Fleming (see "The Electrical Magazine," July, 1906) as indicators of maximum wave intensity.

PRACTICAL telegraphers, however, would not think that perfection had been reached when signals represented by variations in light or luminosity were obtainable. For practical purposes a receiver giving audible signals or signals capable of being readily recorded is preferable. For instance, it was considered a decided advance in the art of sub-

marine cable telegraphy when the Thomson reflecting galvanometer, with its traveling "spot" of light, was displaced by the same inventor's siphon recorder. An objection to the reflecting galvanometer was that it frequently required two operators, one to read the incoming signals and the other to write them down. Possibly, if by some harmless attachment to the eye, corresponding to that of a telephone receiver to the ear, signals could be caused to appear as flashes of light of longer or shorter duration, and that would not at the same time interfere with the ordinary vision of the operator, the aforesaid objection to light signals might be removed; and this may be one of the forthcoming advances in the art. But in the meantime it is to be apprehended that until the practical advent of telepathy, by which, of course, is meant the direct conveyance of intelligence from brain to brain, the ether or some other subtle material acting as the medium, wireless telegraph engineers must continue to devote their talents to improving the present, or more or less similar, indirect Hertzian wave receivers.

CALVIN WINSOR RICE

THE NEW SECRETARY OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

By John W. Lieb, Jr.

SOME months ago considerable interest was excited in engineering circles by the announcement that Prof. Frederick R. Hutton, who had served the American Society of Mechanical Engineers as secretary so long and with such conspicuous success, had signified his intention of retiring.

It was to be expected that many candidates would be mentioned for a position of such honour and with

such wide opportunities for usefulness, and those interested in the welfare of the society were much pleased when they learned that Mr. Calvin Winsor Rice, to whom the position was offered, had consented to serve.

Mr. Rice has seen considerable service in the councils of engineering societies, and last year he was chairman of the committee of papers and meetings of the Mechanical Engineers. By temperament, edu-

cation, and professional experience he is peculiarly qualified to fill the position of secretary of one of the most influential engineering bodies, and it opens to him a career of distinction and wide usefulness.

Mr. Rice was born at Winchester, Mass., on November 4, 1868, and received his early education in the public schools of Boston, New Haven, and Winchester. He entered the Massachusetts Institute of Technology in 1886, graduating from the course in electrical engineering. He was already familiar with the handling of machine tools, and, after some practical experience in the draughting room and in various subordinate positions, was advanced to the position of assistant engineer in the Power and Mining department of the Thomson-Houston Company, at Lynn, Mass. When the consolidation with the General Electric Company took place Mr. Rice was transferred to its Schenectady works. He was soon advanced to a position of greater responsibilities as district engineer of the company, with headquarters at Cincinnati, a field in which his services were called upon in many branches of electrical engineering work,—railway, lighting, power, and mining.

He then turned his attention to mining work, and after service in the Silver Lake Mines, at Silverton, Col., he became connected, as consulting engineer, with the Anaconda Copper Mining Company, of Butte, Mont. There he obtained a wide experience in the development of water-powers, in their transmission electrically to distant points and in the economical handling of large steam

plants. Returning to the East, he was appointed electrical engineer of the Kings County Electric Light & Power Company, and later took part in the engineering work in connection with the consolidation of the lighting plants in the boroughs of Manhattan and the Bronx, of the city of New York, under the auspices of the New York Light, Heat & Power Company, succeeded by the New York Edison Company. As engineer in charge of one of the operating departments of the company and engineer of the company operating the high-tension subways of New York City, he became thoroughly familiar with all branches of central station work.

In 1902 Mr. George Westinghouse was preparing to introduce the Nernst lamp to the American public, and Mr. Rice received a call to direct the work as second vice-president and manager of the Nernst Lamp Company. The year following he returned to the service of the General Electric Company as consulting engineer of the New York office, where he made a specialty of steam engineering, with particular reference to steam turbines.

Mr. Rice is a member of the American Society of Mechanical Engineers, of the American Institute of Electrical Engineers, the Institution of Electrical Engineers of Great Britain, and the American Association for the Advancement of Science. With such a record of professional service and engineering experience to his credit, his friends have every confidence that he will give a good account of himself in his new field of activity.



From Other Points of View

Great Tunnels

Lewis M. Haupt, before the Franklin Institute

THE Hoosac Tunnel, in Massachusetts, five miles long, was commenced in 1854, and prosecuted by private contractors until the State took possession, September 4, 1862. It was enlarged and completed July 1, 1876, when it was officially accepted. The total cost of the railroad and tunnel, forty-four miles, was \$17,322,019, of which \$3,287,835 were interested. The progress was greatly accelerated by the introduction of power drills, 1867, and of nitro-glycerine, in 1870.

The Mt. Cenis project, in the Alps, was first broached by Guiseppe Medail, a Swiss peasant, in 1838, and subsequently, in 1852, M. Colladon suggested driving it by the use of compressed air drills, operated by water-power; but it was not until 1857, after a report by experts, that the Piedmontese Parliament granted a charter and agreed to pay half the estimated cost, which was \$7,760,000, but it ultimately paid for the entire work.

The first blast was fired August 18, 1857, and the headings met December 25, 1870. It was opened for use September 17, 1871. Total length, 42,158 feet, or eight miles. Time, fourteen years in building. Cost, \$14,498,352. Machine drills

were introduced at the north end in 1861 and at the south end in 1863.

The Sutro Tunnel was designed to open up the famous Comstock lode, in Nevada, by providing better drainage and greater accessibility to the mines. The section was 12 × 16 feet, and length 20,351 feet, or nearly four miles. Work was begun October 19, 1869, and completed about 1878.

The contract for the St. Gothard Tunnel was awarded to Mr. Louis Favre, on August 7, 1872, at an estimated cost of \$10,000,000, and was completed in eight years, with a premium of \$1000 per diem for every day saved or a similar penalty for each day lost. With the system of rapid firing and removal of débris great progress was made in each heading, and the first train passed through in 1881.

Its total length is nine and one-quarter miles; time, nine years, five months. The early location of the approaches was placed high on the mountain slopes instead of the valley bottom, adding much to the expense, but this was afterward modified by the use of the spiral tunnel and loops.

Through the Austrian Tyrol a tunnel of 6.38 miles, the Arlberg Tunnel, was driven between 1880 and 1884 at a much more rapid speed than any of its predecessors, at an

estimated cost of \$7,000,000. The time consumed was three years, nine months. Work was conducted very systematically, and construction trains were run by time schedules. In cost, therefore, this work was but \$1,000,000 per mile.

The Simplon Tunnel, which connects Brig, in the valley of the Rhone, with Iselle, on the Diveria, in Italy, is twelve and one-quarter miles in length. The contract was let in September, 1893. The plans contemplated the use of the system proposed for Hoosac, of two single-track parallel tubes 16.5 feet wide, 55.7 feet apart, but connected by oblique galleries at frequent intervals. Only one of them was to be completed to full dimensions, while the second was to be used for subsidiary purposes to provide trackage for construction and ventilation, and to await the demands of traffic for its final enlargement. The cost is reported to be \$15,500,000 to February 24, 1905, when the headings met, thus opening the shortest route by eighty miles between Paris and Milan, and connecting the Atlantic and the Mediterranean. The large amount of water and high temperature (reaching 118 degrees F.) made this work one of unusual difficulty.

Actual work was begun in 1898, so that the average ratio has been nearly two miles a year, and it is a monument to the enterprise and energy of the countries which have contributed so liberally to the colossal work which, at best, will save but a few hours in transit between the Italian seaports and the British Isles.

The feature of the above works is that they have generally been excavated from the ends, without intermediate shafts or slopes. Many more miles of continuous underground ways are now in existence, as in the numerous subways of Continental and American cities, but these have been built largely as open cuts or covered-ways, or with numerous shafts.

Another important class of structures is the sub-aqueous passages connecting great centres of industries and taking the place of bridges. These involve greater difficulties and risks than are to be found in the previous classes, yet to avoid the transfers, delays and risks of ferries or the obstructions due to bridges, ice, and fogs, they are found to be expedient, even at very great cost.

The latest and best practice in works of this kind is illustrated in the extensive system of tubes now completed and under construction by the Pennsylvania Railroad Company, under the direct supervision of Mr. Chas. M. Jacobs, Alfred Noble and others, in and across the rivers surrounding the Island of Manhattan, and connecting its western ramification directly with the greatest seaport of the American Continent, without break of bulk.

Whilst the tube system as used underneath the North River at New York has required much ingenuity to adapt it to its purpose, the general idea was first applied in the pioneer work built under the Thames, at London, by M. I. Brunel, in 1825 to 1846. This structure is 1200 feet long, with two passageways 14 feet wide by 16½ feet high, and is now used by the East London Railway.

The influx of mud and water was so great as to cause the invention of a shield to cover the whole face of the excavation, 38 feet wide and 22½ feet high. An attempt was made to introduce the Beach pneumatic system in New York about the year 1863, but it was untimely, and the traffic had not at that time reached such magnificent proportions as to justify the expense, and there was an aversion by the public to being shot through a hole in the ground. Electric motors were not then available. Again, in 1868-69, W. H. Barlow used a modified form of Brunel's shield in building the "Tower" subway under the Thames. This was circular in section, 8 feet in outside diameter, and was lined with ribbed

cast-iron plates. It was the prototype of the present generally adopted system. In 1889 a pair of tubes, each 10 feet in diameter, was laid under the Thames by Mr. Greathead for the South London Railway by means of an improved shield telescoped over the outer end and pressed forward by jacks, as in the Tower subway.

The earliest sub-aqueous aqueduct tunnels in America were those built at Chicago in 1864-67, two miles long, at a cost of \$457,844, and subsequently extended four miles further for a fresh water supply. A second conduit, 8 feet in diameter and four miles long, was added in 1887-1892, and also at Cleveland in 1869-74, when a conduit 5 feet in diameter and 6606 feet long was built.

In 1888-1902 the Grand Trunk Railroad built a single-track circular tunnel, lined with cast-iron segments, by the use of shields, under the Detroit River, at Sarnia, through soft clay, sand and gravel 6000 feet in length. To-day similar systems of sub-aqueous tunnels are being rapidly and successfully built under the North and East Rivers, flanking the city of New York.

Still another extensive group of tunnels is to be found in the aqueducts for supplying large communities with water. The most conspicuous example of this class is the Croton Aqueduct, for supplying water to the city of New York, thirty-three miles in length and about 14 feet in diameter, crossing the Harlem River by means of an inverted syphon at a depth of 306 feet below the surface.

Amongst the most interesting drainage tunnels may be mentioned the ancient Desague de Huehuetoca, undertaken by Enrique Martinez, a Dutch engineer, in 1607, for draining the basin of the City of Mexico. The tunnel was four miles long and the drain thirteen, but before the lining was completed a great flood caused it to cave in. As a reward for his effort, the engineer was im-

prisoned for three years, and when released he was ordered to make an open cut, in which he spent the rest of his life. But the work was continued for 120 years, yet it was not made deep enough to relieve the basin to any great extent. In 1888 another tunnel was built, six miles long and 150 square feet in section, supplemented by twenty-seven miles of large canals. This tunnel had twenty-four shafts, varying in depth from 75 to 325 feet, and a discharge capacity of 450 cubic feet per second.

Ineffectiveness of Night Work

From "The Iron Age."

THE modern cost system, coupled with lessons taught by experience, is responsible for the fact that in many lines of manufacture, in which skill is an important element, employers avoid to the greatest possible extent the running of their works overtime or with night shifts. Formerly, during times of great demand, most works ran with night gangs, on the theory that production could be increased correspondingly with the additional number of hours worked above the regular day's schedule. While it was well recognized that practice did not work out according to theory, there was little realization of the actual difference between shop production during a night hour as compared to a day hour. The cost system put the matter beyond a possibility of doubt, demonstrating that the difference in production is really very large.

Of course where production depends wholly on the number of hours which a machine operates, night work may be as profitable as day work. Automatic machinery will produce as much by night as by day, and frequently one finds that this class of production is maintained night and day, power being bought, if necessary, for the purpose of running motors, in order that the shop engines may be idle. Coarser pro-

ducts, where brute strength or elementary skill is the chief element in the make-up of the workman, may be advantageously manufactured at night, though the production is seldom that of a day force. But when it comes to such labor that the skill of the operator is the chief factor of production, or at least a very important factor, then the showing of night labour is much less satisfactory. In the machine tool shop or in other works building machinery, night work has been shown to be unprofitable, though it may be necessary to resort to it at times in order to meet some particular demand upon the manufacturer's productive resources. The same thing is true of overtime work. As the head of one of the largest machine tool manufacturing concerns in the country has put it, overtime work may be employed with profit during a short period "to get the manufacturer over a hill, but when it comes to trying to maintain the business on a plateau above the plain of normal maximum production then the longer hours do not pay."

Men cannot and will not do the same work at night as they do in the day time. They have not the same energy; they are not living the natural existence, for, by reversing the periods of waking hours and sleep when they are not accustomed to it the normal poise is upset. Men working nights are very apt to take insufficient sleep. The usual practice of working them twelve hours a night for five nights, thus making up the sixty-hour week, leaves the time from Saturday morning to Monday evening at their free disposal, and they then usually return to the normal hours of rest, sleeping Saturday and Sunday nights and keeping awake from Monday morning, through the day and thence on through the working hours of Monday night, with drowsiness and lethargy as the natural result. Overtime workers wear out after a short time, and must be permitted to recuperate.

Presuming that a high-class workman takes the best of care of himself while working nights, admitting that he works the best he is capable of doing during his night hours, he cannot accomplish so much and so good work on the average as in the day time. The light is not so good as daylight; he has normally less energy, as any one can observe in the difference of appearance of a night force or a day force entering the works at 6 o'clock in the evening or at 7 o'clock in the morning; there is not the same keenness of the senses; neither the eye nor the brain has the same perception. The master of the instrument or the tool is not at his best. With the less skilled or less conscientious workman the difference is even more marked. He spoils more work, and does it not only less carefully but less rapidly. He is more likely to shirk under the night foreman than during the daytime, when the eyes of the superintendent are apt to fall upon him, or the employer himself may chance to pass by. He is more prone to fail to report for duty, led away by the allurements of an evening's pleasure.

Putting the deadly test of the cost system upon the night force, and the difference as compared to the day force is very important, so much so that, in some instances, the night force may be said to operate as an expense rather than as a source of profit. It is difficult to get the best men to work nights, during a period in the labour market which goes with a demand great enough to make night work necessary. To-day two complete and entirely capable working forces in a machine shop would be well-nigh impossible, for there are more than enough places for good men during the daytime. Even very high wages could hardly accomplish the getting together of a night force as capable as would be required to bring about the best possible results.

One company tried the experiment of putting its best workmen in a

night force and filled their places during the day with the best that could be obtained. The experiment was abandoned because it was demonstrated that the good men did not produce the same work they did during the day, nor so much of it, and, of course, their substitutes during the day were inferior in skill, yet it was considered more profitable to work the good men in this combination than to trust the less reliable and less skillful mechanics in the night force. It was proved that the night gang did not pay, excepting as a bridge upon which to pass over an unusual emergency of orders. Were the reverse true, if forces of men could be got together to form two complete and nearly equally effective forces, then the machine tool market would be less afflicted with delays in deliveries. But even with an ideal corps of mechanics the profit of the night force would be much less than that of the day men.

Locomotive Problems

George M. Basford, before the Mechanical Engineering Society of Purdue University

AS to the locomotive problems of the present, we have a few like these,—Shall the next lot of passenger locomotives be single or double expansion? Shall we experiment to-day with superheating? Shall we order balanced compounds? Shall we not adopt improved valve gear? For the next very heavy freight locomotives, shall we order articulated compounds? Shall we brave the criticisms of those who worship simplicity and order really better locomotives, even if a few complications are involved? In the shop problem, shall we or shall we not organize and operate large plants upon the well-understood principles which have made large manufacturing enterprises successful? In the next order for 10,000 cars, shall we use all wood, all steel, or composite construction?

These are live questions, and those who are to decide them need to understand the reasons why they are presented and why they are pressing.

Shall the next lot of passenger locomotives be single or double expansion? Compounds, because of their favourable use of steam by dividing the range of expansion and the range of temperature changed in the cylinders, are more economical in the use of steam than are simple engines. This improves the efficiency of the locomotive as an operating unit, which is more important than economy. There is less cylinder condensation in a compound because the division of the expansion between the two cylinders reduces the range of temperature, and, therefore, reduces the amount of moisture condensed from the incoming steam for the next stroke.

A further advantage in the use of compound cylinders which applies to the three and four-cylinder type lies in the fact that the steam is divided into smaller installments and not so much steam is required to pass through a given number of steam ports and passages. This renders a three and four-cylinder compound "quicker on its feet" than single-expansion locomotives of the same capacity, and, as a matter of fact, the highest speeds in regular train service in the world are made with compound locomotives.

It may seem strange, in view of the superior economy of compound locomotives, that they have not been adopted generally in place of single-expansion locomotives. Compounds are apparently increasing in favour at the present time, and this is to be explained on the ground of the increased capacity which they render available rather than because of their superior economy. It is claimed by those who have used compounds and discarded them that the additional cost of maintenance, because of the somewhat increased complication, more than offsets the advantage gained by saving a little fuel. While

this may have been true some years ago, it is not believed to apply to the more recent types of compounds, and it may even be claimed at the present time that the feature of economy may be disregarded. This is because of the very much more important attribute of the compound in applying increased capacity. At the present time railroad men are so anxious to secure the utmost possible capacity that they are willing to accept some additional trouble and expense in maintenance in order to secure the additional power which every railroad now requires in order to deal with trains of increasing weights and speeds. Reliability of service in summer and winter is now becoming very important in competitive passenger service. For this, reserve capacity is necessary.

Those who are most competent to judge believe that the locomotive of the future is sure to be a compound.

Shall we experiment to-day with superheating? Superheated steam offers a very attractive field in connection with locomotive development. In German practice it has been remarkably successful, and the Canadian Pacific Railway has practically duplicated the satisfactory results obtained in Germany. A number of experiments are now being made in America, promising very satisfactory results. In short, superheating is one of the fundamental questions in locomotive practice which is worthy of most careful attention at this time.

Superheating does not seem to be antagonistic to compounding, but it serves in the same general direction to reduce heat losses in the cylinders. Condensation of steam in locomotive cylinders and passages robs the locomotive of a great deal of its power, and, in cold climates, this becomes a serious matter. It will always be difficult to thoroughly protect the cylinders and steam passages from radiation, and, therefore, other precautions may be necessary to prevent the loss of heat from lessening

the power of the locomotive. Superheated steam, coming into the cylinders at high temperature, as it does, permits of a larger loss of heat before producing condensation than is possible with saturated steam where the margin for loss without condensation is very small, and in this lies the chief advantage of its employment. Superheated steam is also quicker than saturated steam in its movements through passages and ports, as is proven by the fact that in Germany 7-inch piston valves suffice for ordinary passenger locomotives.

Such a principle as this cannot be applied to a locomotive without incurring some trouble and expense. While the improvement in the efficiency and economy of the locomotive is very readily attained, it is quite possible that it may be attained at too great an expense of restricted mileage and cost of maintenance, and it is always necessary to nurse a new development in order to make it practically successful. The possibilities of superheated steam at the present time seem to be exceedingly important, and it is perfectly safe to spend the time and money necessary for experimenting because of the practical certainty of the results.

Shall we order balanced compounds? The subject of balanced compounds really requires a paper by itself. Locomotives have become too large to permit of continuing indefinitely the mere increase of size and weight. More scientific development is needed. The usual methods of counterbalancing answer very well for comparatively light locomotives, but as locomotives become larger and the parts become heavier, the internal stresses upon the engine itself, due to the inertia of the parts, and the effect upon the track of the unbalanced counterweights, make it necessary to devise a better scheme of balancing.

In ordinary practice counterweights are added to the driving wheels

for the purpose of balancing the reciprocating parts, but the revolving weights themselves need balancing when near the top and bottom of their paths. When in these positions the counterbalance weights tend to change the weight on the driving wheels, due to their centrifugal action, acting vertically upward when the weights are near the top of their path, and acting vertically downward when they are near the bottom. The counterweights, therefore, tend to lift the locomotive in the one case, and tend to increase the weight on the rails in the other case. This causes the so-called "hammer blow" upon the rail, and because this so-called "hammer blow" sometimes amounts to 25 per cent. of the static weight on the rails, it becomes exceedingly important in limiting the weight allowed upon driving wheels. By using four-cylinders and balancing reciprocating parts with other reciprocating parts, and revolving weights with revolving weights, a practically constant pressure on the rail is secured, which renders it permissible to increase the weight on the driving wheels without increasing the destructiveness upon the track. By this permissible increase of driving-wheel load a larger boiler may be carried, which is greatly to be desired in locomotive practice to-day.

For the next heavy freight locomotives, shall we order articulated compounds? Heretofore the locomotive has grown generally in size and weight, without radical change in principle, to meet conditions of growth which cannot properly be made through the application of the brute strength idea in design. Large freight locomotives of ordinary types now involve single parts so large as to be difficult to handle in the shop. Their very size gives evidence of the stresses to which they are subjected, and it is believed that the time has arrived for dividing the power and work of the freight locomotive into a larger number of parts, as is done in the case of the Mallet articulated

compound, which has now been successfully running for over a year on the Baltimore & Ohio Railroad. This locomotive weighs 477,500 pounds, including tender, and is the heaviest and most powerful ever built. This locomotive has operated so successfully as to practically establish the principle of articulated compound for locomotives which are not nearly so heavy. This general subject of the freight locomotive is one which now needs, and will continue to need, the attention of those who are preparing to deal with the problems of the next few years.

Use of Oxygen in Removing Blast-Furnace Obstructions

The Chevalier C. de Schwarz (Liège), before the Iron and Steel Institute

ALL experienced blast-furnace engineers are acquainted with the great inconvenience, anxiety, and even, in certain circumstances, danger caused by the taphole of a blast furnace becoming closed up by solid iron, so that it cannot be opened by means of the ordinary appliances without a certain lapse of time. There is the danger of the liquid iron accumulating on the hearth of the blast furnace and reaching the slag and the blast tuyeres, thus causing serious disturbances and sometimes explosions. It often becomes necessary to make a new taphole higher up, and to reduce or to stop the blast temporarily, which may result in the formation of scaffolds or other serious inconveniences well known to blast-furnace engineers.

The case is still more serious if the blast tuyeres of the furnace get closed up by solid iron, either partially or entirely, owing to a scaffold dropping suddenly, or from other causes. Should it in such a case be impossible to get a hole through the iron blocking up the tuyeres within a certain time, a new temporary tuyere, at a higher level, must be applied, and even this remedy often

does not have the desired effect. There are, in fact, few cases in metallurgical practice where quick and effective measures are of greater importance and more imminently necessary than those mentioned above.

Hitherto the opening of tapholes closed up by solid iron has usually been effected by forcing a hole through the iron by means of a steel bar driven by hand-hammers. If hand methods do not suffice, a heavy "ram," suspended on chains and worked by a dozen men, is employed. However, it sometimes happens that the steel bar snaps off, leaving the broken end in the hole already made, so that the liquid iron cools down in coming out, and solidifies in front of the taphole, thus making matters worse than they were before.

Coke and heated blast, as well as petroleum, are sometimes employed for opening a closed-up taphole or tuyere, but these require too long a time to take effect, and, in the case of a tuyere, the latter is, as a rule, utterly destroyed by the operation. A strong electric current of from 400 to 1000 amperes has also been used for opening tapholes, but this method is similarly open to the objection that it does not work quickly enough, besides which it is very expensive.

The application of compressed oxygen in such cases has completely overcome all these difficulties, as a closed taphole or tuyere can be opened in a few minutes only, besides which the method has the merit of being exceedingly simple and cheap, as will be seen from the following description.

The iron to be burned through (pierced) is first heated from outside, at the spot selected for making the hole, by means of an oxy-hydrogen flame which, up to now, has proved to be the most useful for the purpose. It can, however, be replaced by any other combustible gas in case of necessity.

The hydrogen and the oxygen gas

are compressed into two separate steel flasks, each flask being provided with a suitable outlet valve, in order to regulate the pressure and the quantity of the escaping gas according to requirement. The "burner" consists of an outer and an inner tube, the outer tube supplying the hydrogen and the inner tube the oxygen. This simple appliance is worked as follows:—

The hydrogen is allowed to escape first, and is lighted, after which the stream of oxygen is turned on. The pressure of both gases is first kept low, but gradually raised and regulated in such a way as to give a very hot flame, which heats the spot upon which it impinges to a white heat. The pressure of the oxygen is then raised to such an extent that the iron commences to burn, which is shown by sparks being thrown about.

The pressure of the oxygen is now further raised to 30 atmospheres and above, whilst the supply of hydrogen is entirely stopped. It is now the iron alone which burns, thus replacing the hydrogen as a combustible, whereby, as shown hereafter, a degree of heat is developed which far surpasses that produced by means of oxy-hydrogen gas. The high pressure of the escaping oxygen, at the same time, serves to force out all the molten iron, thus keeping the hole burnt through perfectly clean throughout the operation. It can be shown that a solid block of cold iron or steel, say 16 inches thick, can in this way be pierced within one or two minutes.

The heating effect of the oxy-hydrogen flame alone is far too low to serve the purpose of opening closed-up tapholes or tuyeres. This is principally due to the fact that (on account of the comparatively great volume taken up by hydrogen) the loss of heat through derivation is much too large, as compared with iron, taking both, as in our case, as combustible matters into account.

On burning one kilogramme of

hydrogen (with oxygen) 13,057 calories are produced, whilst when burning iron (with oxygen) only 748 calories are generated. However, one kilogramme of hydrogen occupies 87,234 times as much space as one kilogramme of iron. Therefore, a certain volume of iron, when burning with oxygen, produces about 5000 times as much heat as an equal volume of hydrogen in equal circumstances.

When iron burns in oxygen the heat evolved is concentrated on a comparatively very small area. This explains the enormously high temperature produced, and the quick action, as mentioned before, notwithstanding that, at the same time, a considerable amount of cold is produced, owing to the expansion of the compressed oxygen after leaving the steel flask. This shows itself at the tube leading the oxygen from the flask to the "burner," which becomes coated with ice, the temperature of the tube being only about 14 degrees Fahr. The process, above described, yields remarkable results when employed for opening a blast or slag tuyere blocked up by iron, because the great heat produced when iron burns with oxygen might lead to the conclusion that the tuyere in question must be melted away, taking the thinness of metal in a tuyere into consideration. This, however, is not the case. Experience has shown that, for instance, a slag tuyere of only 1½-inch inner diameter can be thoroughly cleaned from all the iron adhering to it without being injured in any way. The tuyere does not get heated at all, but cools down, considering that the temperature of the oxygen, coming from the tube, is, as already stated, reduced below freezing point owing to expansion.

The oxygen process has been successfully applied for opening tapholes of open-hearth furnaces where they have become blocked up with iron or steel. It is of great importance that no delay should occur in tapping an open-hearth furnace as soon as the

liquid metal has reached the desired degree of decarbonization, as otherwise its composition might change, owing to the delay, to such an extent as to render it useless for the desired purpose. The new process overcomes difficulties of this nature in a few minutes.

Experiments are also being made as to the employment of the new process for improving steel ingots by removing the "pipe" caused in the upper portion owing to shrinkage during cooling. The crust of solid steel or iron above the pipe is burnt through in the way already described within less than a minute, and superheated liquid metal of the same quality as the rest of the ingot poured in. This thoroughly fills up the pipe. The experiments are not completed as yet, but the results so far obtained seem to promise final success.

The oxygen process has also been successfully employed in removing dead-heads or runners on steel castings. This is of special value in cases where the hardness of the steel casting is such as to resist the action of the cutting tool at the place where the dead-head or runner is joined to the casting.

In rolling mills, where interruptions of work are very costly, the oxygen process can be advantageously employed in melting through and quickly removing any broken shaft or axletree from couplings, fly-wheels, etc., instead of causing long delay and expense in doing this work by means of chisels and drills.

The oxygen process has also been successfully employed for piercing armour plates for warships and armoured turrets. This is of special importance in case such plates are of hard metal. A hole through such a plate, of say 9-inch thickness, would require two or three hours if drilled in the ordinary way, whilst with compressed oxygen this work can be done within fifteen to twenty seconds. This remark applies also to the manufacture of hollowed weld-

less steel goods, either pressed or cast, especially if hard steel is used where the driving in of a treble might spoil the article in question.

Whilst, as already mentioned, oxy-hydrogen has proved the most convenient for producing the necessary initial heat, before applying the oxygen gas alone, in order to open blocked-up tapholes or tuyeres in furnaces, the electric current has proved more convenient for the same purpose if armour plates, steel castings, etc., are to be pierced. A current of from 4 to 6 volts and 200 to 220 amperes is quite sufficient to produce the necessary initial heat before applying the oxygen.

The oxygen process above described was invented and first practically applied by Dr. E. Menne, engineer to the Cologne Müssener Bergwerks Aktien Verein, at Creuzthal, in Westphalia. Some improvements have been effected and carried into practical operations by the Société Anonyme Oxhydrique Internationale, at Brussels, for cutting boiler plates, tubes, etc., so quickly and accurately that the oxygen process has secured favour as a trustworthy method for this purpose. The arrangement consists essentially of two tubes which

can be placed one behind the other, the first tube supplying oxy-hydrogen gas, and the second oxygen gas. The oxy-hydrogen heats the plate up to a white heat, and the compressed oxygen burns (cuts) the plate exactly as desired. The apparatus for guiding the two tubes works in such an easy and exact manner that the slightest pressure of the finger-tips suffices to guide it as desired.

Finally, it may also be permissible to take the financial outlook of the oxygen process into consideration. The principal outlay is that for the oxygen gas, which, at present, costs about 3s. for 1000 cubic feet; but a reduction in this price is expected.

For opening a blocked-up taphole or a tuyere, as a rule, not more than 8 or 10 cubic feet of oxygen are required; in exceptional cases, however, from 20 to 40 cubic feet of oxygen gas are necessary.

The apparatus itself is very simple and inexpensive. It consists of two steel flasks, each with a reducing valve, and of a few yards of iron tubes and armoured hose. Several blast-furnace works in England, Germany, Austria, France, and Belgium have already adopted the process, with satisfactory results.



FRANK H. TAYLOR

VICE-PRESIDENT OF THE YALE & TOWNE MANUFACTURING CO.

SEE PAGE 230

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THE GAS TURBINE

PRACTICAL RESULTS WITH ACTUAL OPERATIVE MACHINES IN FRANCE

By René Armengaud

ALTHOUGH there have been various academic discussions upon the possibility of producing a practical power turbine impelled by the action of gases of combustion, the whole subject has been treated, with but few exceptions, as a matter entirely in the future, and even so experienced and acute an observer as Mr. Dugald Clerk, in a recent address before the Junior Institution of Engineers, in London, stated that he had not been able to find any gas turbine in a state of effective rotation doing useful work. As a matter of fact, however, an effective gas turbine has been in successful operation at the establishment of the Société des Turbomoteurs, at Saint Denis, near Paris, for many months, and experiments are even now being conducted with this machine, not to see if it will nearly turn round, but to determine its mechanical efficiency, in comparison with the computed results. This machine, due to the combined efforts of M. Armengaud and Lemale, was described in a general manner by M. René Armengaud at the recent International Congress held in connection with the exposition at Liège, but the work has

made rapid progress since that time, and we now have later data and information from our colleague, M. Armengaud, which will prove, we believe, of the utmost interest to the mechanical engineering profession. The illustrations speak for themselves, showing as they do a complete machine as it has been in operation for some time past, and it is intended to follow up this whole subject of the gas, or combustion, turbine in these pages from month to month, giving the latest information in all departments of the subject as it is developed.—THE EDITOR.

Heat motors in general service at the present time may be grouped into the following classes:

1. Alternating steam motors (reciprocating steam engines).
2. Alternating combustion motors (reciprocating gas engines).
3. Continuous steam motors (steam turbines).
4. Continuous combustion motors (gas turbines).

Of these various machines the latest, and certainly the least known, is that which appears to have a most interesting future, the gas turbine, and it is this which I propose

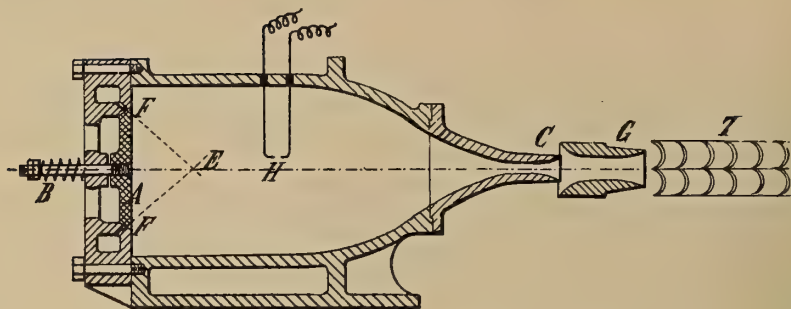


FIG. 1.—GENERAL ARRANGEMENT OF EXPLOSION GAS TURBINE

to discuss in the present article.

A successful gas turbine aims to combine the great advantages of the gas engine, including the elimination of the steam boiler and a high thermal efficiency, with the special advantages of the steam turbine, i. e., simplicity of construction, lightness, and the greatly desired property of continuous motion in one direction, with the accompanying features of control and regulation.

The various plans which have been discussed for the design of the gas turbine may be divided into three groups: hot-air turbines, explosion turbines, and combustion turbines.

So far as the first group is concerned, I have not attempted to make any investigations in this direction, believing this system to offer few advantages. The only machine of this kind of which I have any knowledge is that of Dr. Stolze, of Charlottenburg, of which the following description is abstracted from his patents.* Air is compressed by means of a helicoidal compressor to about $1\frac{1}{2}$ atmospheres. This air, after having circulated about a furnace, expands, and is then passed through a turbine attached to the same shaft as the compressor.

In the case of the second group, the explosion turbines, the air compressor is eliminated or greatly simplified. The explosive mixture is formed in the same chamber in which it is ignited, being either at atmos-

pheric pressure or slightly above, and by its expansion, consequent upon the explosion, it acts upon the turbine wheel. The principle of such a machine is shown in Fig. 1. The explosion chamber is closed at the back by a valve *A* held to its seat by a light spring *B*, the chamber having an expanding-nozzle opening at *C*. The gas enters at small openings, as at *E* under the seat of the valve, and the air is admitted at *F*, the mixture being ignited electrically at *H*, and discharged through the nozzle *C* upon the buckets of the turbine

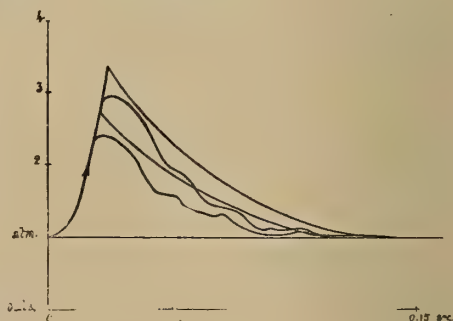


FIG. 2.—EXPLOSION TURBINE DIAGRAM

wheel *T*. The discharged gases pass through an induced current nozzle *G* which acts to reduce the temperature of the issuing gases and lower the velocity of the jet as it acts upon the turbine wheel.

Such an apparatus, when properly proportioned, will make about three explosions per second, and will continue to run automatically after it has once been started.

Various theories have been ad-

* A fully illustrated account of the Stolze turbine will appear in an early issue of Cassier's Magazine.—Editor.

vanced to explain the action of this device. The most satisfactory explanation of the periodic action is that of the sudden cooling of the chamber after each explosion. This cooling causes a corresponding drop in the pressure, followed by the open-

advantage over the corresponding cycle for a combustion turbine. The specific heat at constant volume being lower than the specific heat at constant pressure, the same quantity of heat acting upon the same mass of gas, should produce a higher tem-

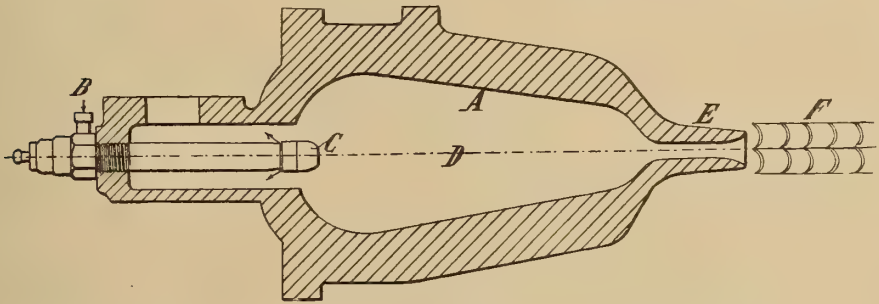


FIG. 3.—COMBUSTION GAS TURBINE

A.—Combustion Chamber. B.—Fuel Inlet. C.—Fuel Sprayer. E.—Expansion Nozzle. F.—Turbine.

ing of the valve *A* and the aspiration of the air and gas, and as soon as the explosive mixture reaches the igniter a fresh explosion follows. In Fig. 2, the variations in pressure in the chamber are shown as a function

perature after the explosion than after a combustion. Since, according to the principle of Carnot, the efficiency is proportional to the maximum temperature of the fluid before expansion, the explosion turbine

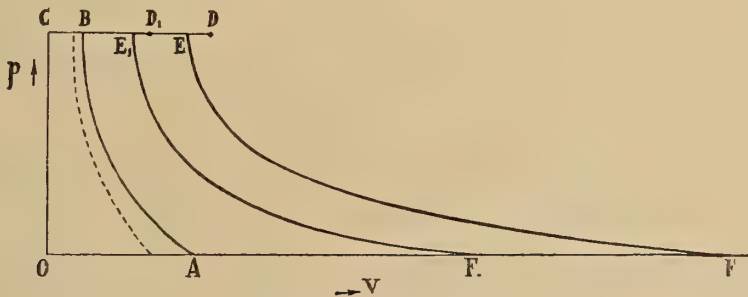


FIG. 4.—DIAGRAM FOR COMBUSTION TURBINE

of time. The maximum effective pressure ranges from 2 to 3 kilogrammes per square centimeter, or about 30 to 45 pounds per square inch, although the theoretical pressure in such an open vessel should reach 4 kilogrammes, so that the mixture of the gas and air is probably imperfect.

Theoretically, the explosion turbine should have a certain thermal

should be more efficient than the combustion turbine.

Unfortunately the high velocities of discharge of the gases, and the variations in the pressure render it impracticable to realize more than a small fraction of the energy of the jet upon the wheel. Thus, the theoretical efficiency of such a machine should be about 16 per cent., while the actual performance does not ex-

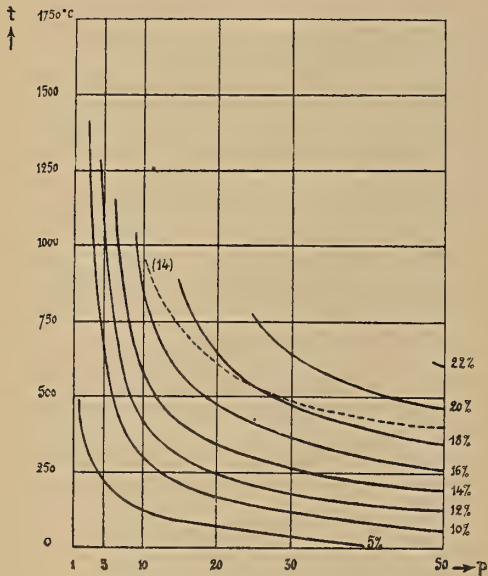


FIG. 5.—GAS-TURBINE ECONOMY CURVES

ceed 3 to 4 per cent. In addition to this defect there are operative difficulties with the springs and valves, and the frequent breakages and delicate adjustments have rendered experiments to improve the apparatus unsatisfactory.

There remains then, the combustion turbine, which, in spite of the necessity for an air compressor, is greatly to be preferred, especially for large units. This machine consists in principle of a combustion chamber *A* Fig. 3, supplied by a continuous current of compressed air, and also by a continuous supply of liquid fuel, gasoline, petroleum, or the like, under pressure through a tube *B*, the mixture being ignited at the start by a platinum wire *C*, the combustion developing a constant temperature of about 1800 degrees C. in the chamber *D*. The fluid products of combustion are then continuously discharged through a nozzle *E*, upon the buckets of the turbine wheel *F*.

The principal defect in this apparatus in comparison with the reciprocating gas engine is the necessity for a separate air compressor, instead of having the compression of the charge effected in the motor

itself. This defect is partially remedied by the diminution of the losses through the walls, and by the possibility of an expansion which is practically adiabatic. The combustion is also more complete than is possible in a working cylinder, and all the products of combustion are utilized.

The action of a combustion turbine is graphically shown in Fig. 4. In this diagram the area *OABC* represents the energy required for the air compressor. The combustion of the liquid fuel increases the volume from *CB* to *CD*. If any vapor of water is introduced, this volume will be diminished from *CD* to *CD₁*, while at the same time its mass increases the volume of *CD₁* to *CE*. The effective energy exerted by the turbine will be represented by the area *OFEC* and that available after the deduction of the work of compression will be *AFEB*.

In endeavoring to produce such a cycle in an actual working machine, the following practical difficulties must be overcome:

A gaseous fluid moving at a high velocity must be kept constantly ignited, by a device which must not be affected by the high temperature of the combustion chamber.

The mixture of the combustible and the air must be made as perfect as possible.

The injurious action of the gaseous products at a high temperature upon the parts of the apparatus, and upon the turbine wheel itself, must be prevented.

For three years a machine complying with these conditions has been running successfully in the shops of the Société des Turbomoteurs at Paris, this apparatus being the Armengaud-Lemale turbine, of which some further description will be given.

The original machine was made from a de Laval steam turbine of 25 H. P., arranged to be operated with compressed air instead of steam. The air was supplied at any desired pressure from a high-speed compres-

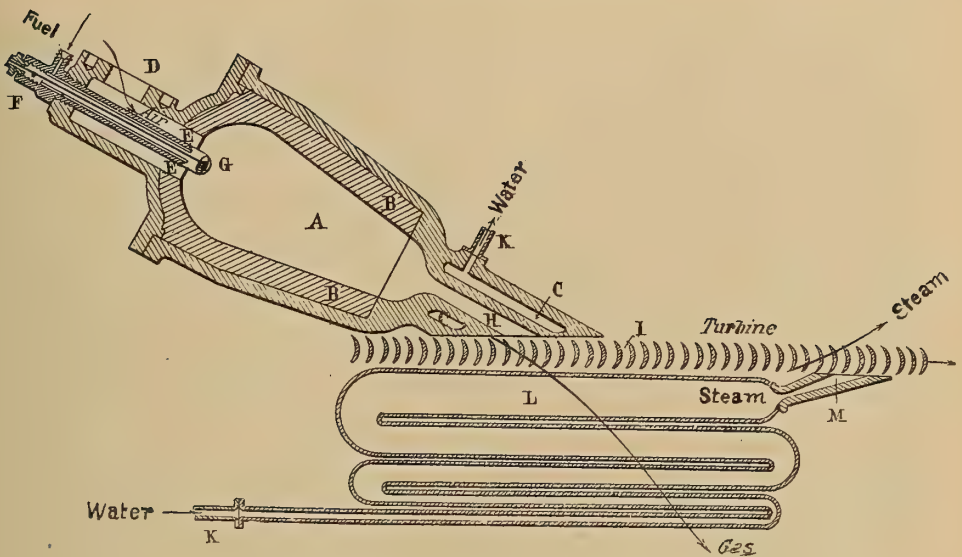


FIG. 6.—MIXED GAS AND STEAM TURBINE

Air enters at D, fuel at F, the ignition is made at G. The combustion chamber A is lined with carborundum. The nozzle H is water-jacketed, and the hot water passes to the steam generator L, which is heated by the exhaust gases from the turbine. The steam acts to propel and cool the wheel by the nozzle M.

sor, of which the efficiency had been closely determined, while prolongations of the pipe which connected the compressor to the turbine formed the combustion chamber. At the entrance of each chamber the gasoline, mixed with the air, was ignited by an incandescent platinum wire, this ignition being necessary only at the starting of the operation, the combustion being maintained continuously thereafter at constant pressure. The combustion chambers were lined with refractory material, and a temperature of about 1800 degrees C. was produced. In order to reduce the temperature to practical limits the chamber was cooled by the introduction of vapor of water generated in a spiral imbedded in a portion of the combustion chamber. The steam thus produced was allowed to mingle with the gases of combustion before expansion in such proportion that the temperature of the mixture was about 400 degrees C.

Although this apparatus was necessarily crude and not proportioned in such a manner as to give the best

results, it enabled the conditions essential for a good efficiency to be determined.

Among the practical points thus determined were proofs that it was entirely possible to maintain the combustion chamber, turbine wheel, and fuel pulverizer in operative condition. The experiments also showed it to be practicable to maintain a very high temperature continuously in the actual combustion chamber, and, by means of this high heat, to secure a perfect combustion of any combustible. The work of compression having been carefully ascertained for the purpose of deducting it from the brake power developed by the entire machine, it appeared that even with this imperfect apparatus the total power was about double that necessary to drive the compressor. This result was attained with a pressure of about 10 kilogrammes per square centimeter, and a temperature of 400° degrees C. at the exhaust.

As has already been said, the excessively high temperatures developed were reduced in the earlier experi-

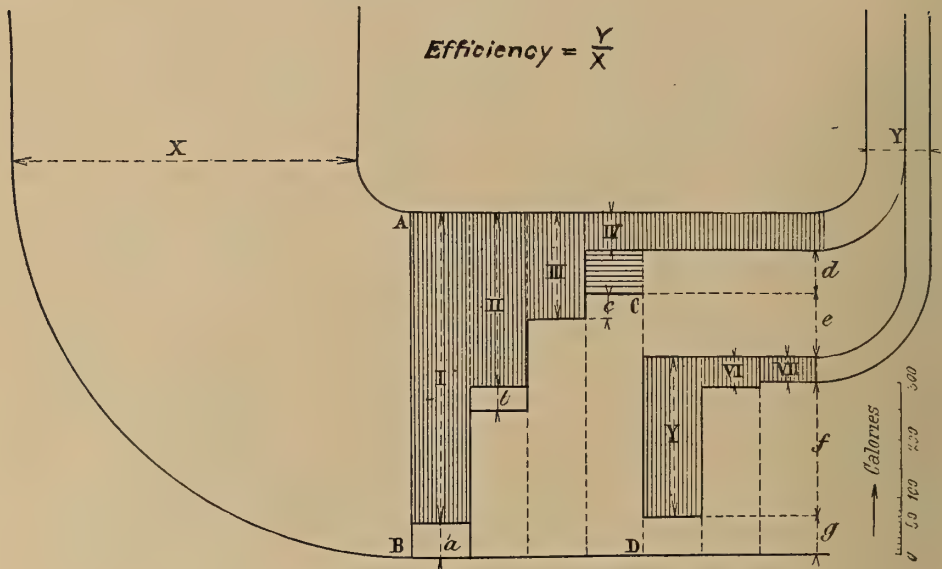


FIG. 7.—HEAT BALANCE DIAGRAM FOR MIXED GAS TURBINE

I.—Total energy developed by the combustion of the fuel. II.—Kinetic energy available at the discharge of the nozzle. III.—Energy developed on the turbine wheel. IV.—Energy developed less the power required to drive the compressor. V.—Energy recovered in the steam. VI.—Energy available in the expanding steam. VII.—Energy developed by the steam on the wheel. X.—Total energy contained in the fuel. Y.—Total energy produced in indicated work. *a*.—Radiation losses from the combustion chamber. *b*.—Loss in the nozzle. *c*.—Compressor losses. *d*.—Theoretical work of compression. *e*.—Radiation losses from the turbine. *f*.—Losses in the exhaust steam. *g*.—Losses in the exhaust gases

ments by mixing a certain quantity of steam with the gases of combustion before expansion. This method, while accomplishing the result desired, also acted to lower the efficiency of the turbine, doubtless because of the latent heat of vaporization lost in the exhaust. In the diagram, Fig. 5, the curves show the manner in which the economical performance of this machine varied, represented as a function of the upper pressure and of the temperature of the exhaust gases. This diagram has been computed upon a basis of 60 per cent. efficiency of the turbine wheel, and 80 per cent. of the compressor. For example, with a pressure of 30 kilogrammes per square centimeter, and an exhaust temperature of 450 degrees C., an efficiency of 18 per cent. is obtained.

It thus appears that the efficiency depends both upon the pressure and upon the temperature of the exhaust gases. In order to obtain the best

efficiency, therefore, it is necessary to prevent cooling the gases before expansion, either by introducing steam into the combustion chamber, or otherwise, and to effect the greatest possible reduction in temperature in the expansion alone.

The difficulties accompanying the high temperatures may be met in the case of the combustion chamber and other fixed parts by the use of a water jacket and by the employment of a refractory lining, and the real difficulties are reached only when it becomes necessary to provide for the effect of the highly heated fluid upon the rotating metallic wheel, already weakened by the heavy centrifugal stresses to which it is necessarily subjected.

The most practical way of keeping the turbine wheel cool is to follow the jet of hot gases by another jet of a low temperature so that the buckets of the wheel pass successively through alternate hot and cool zones,

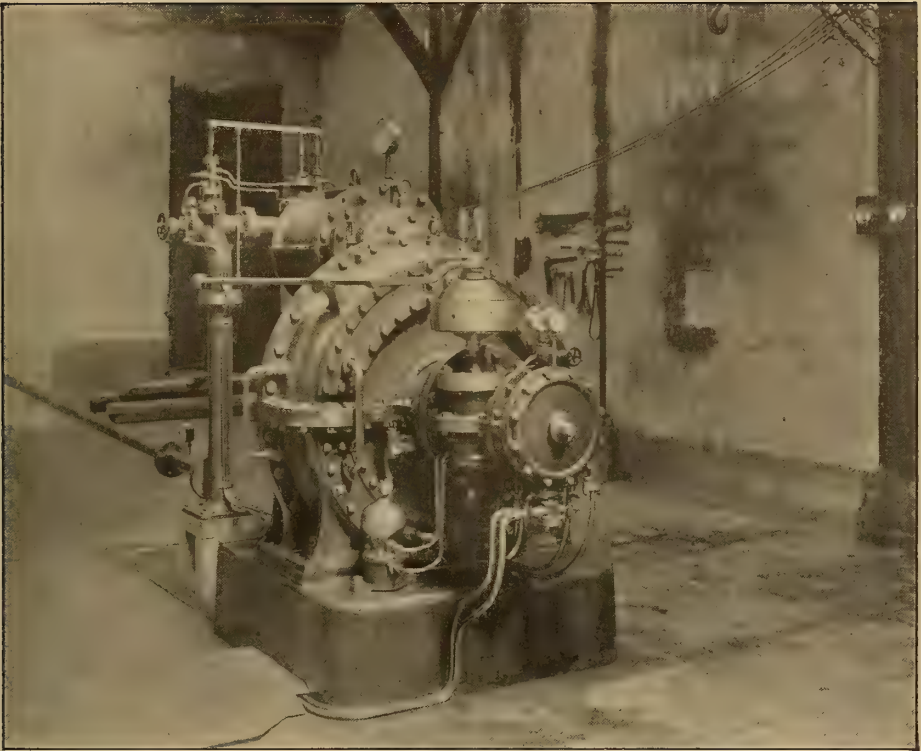


FIG. 8.—THE ARMENGAUD AND LEMALE GAS TURBINE

A view of the 500 horse-power turbine in the experimental laboratory at St. Denis

the average temperature of the two jets being sufficiently low to prevent injury to the metal. The low temperature jet found most practicable is that of low-pressure steam, and this is readily provided from the water jacket and from a device arranged as a regenerator in connection with the exhaust gases.

This arrangement, shown in Fig. 6, gives a general idea of the system. The air from the compressor enters at *D* and is mixed with the liquid fuel in the concentric nozzle *EE* and ignited by the platinum wire at *G*. The combustion takes place continuously at constant pressure in the chamber *A*, and the products of combustion are discharged through the expansion nozzle *H* upon the buckets of the turbine wheel *I*. The nozzle itself is protected by a water jacket *C*, the water leaving the jacket at

K. On the other side of the wheel there is arranged a sort of flash steam generator *L*, this being composed of a serpentine pipe of continually increasing diameter, the water entering at the small end at *K*, this entrance forming a part of the discharge pipe from the water jacket of the nozzle *H*. The steam generator *L* is placed in the path of the exhaust gases leaving the turbine wheel, and these highly-heated gases furnish the heat necessary to convert the water into steam, the vapor thus produced being discharged through the nozzle *M* upon the turbine wheel, thus acting both to aid in the propulsion and to form a zone of comparatively low temperature to abstract heat from the wheel. By this arrangement it is possible to reduce the temperature of the wheel to practicable limits, provided the tempera-

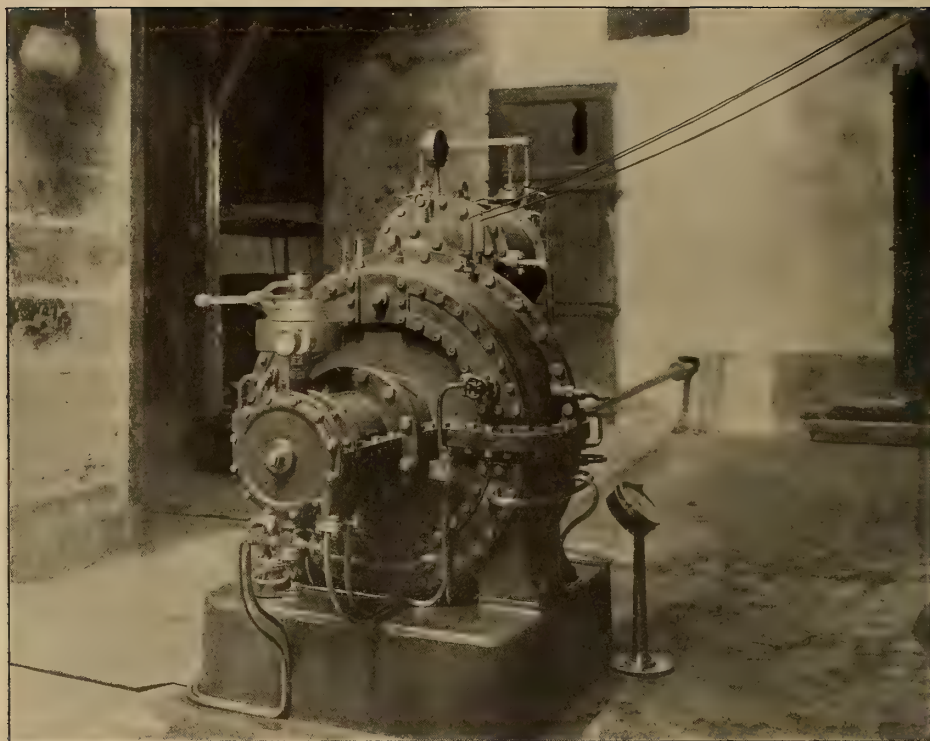


FIG. 9.—THE ARMENGAUD AND LEMALE GAS TURBINE

This view and the preceding one show the wheel casing, governor, and general arrangement

ture of the exhaust gases is sufficiently high to produce enough steam. That is, the expansion of the gases in the nozzle must not lower their pressure and temperature so far as to keep down the volume of steam too low. In such case it is always practicable to admit a small quantity of superheated steam into the combustion chamber and thus obtain the required temperature without affecting the efficiency of the machine too much.

The general heat balance of a gas turbine using a steam regenerator according to the above plan is shown in Fig. 7, in which the total quantity of energy produced by the fuel is represented by the dimension X , and the various losses indicated by the cross-hatched portions in the body of the diagram. The efficiency of the machine is then obtained as the ratio $Y : X$, Y being composed of two

parts, one of which is obtained from the action of the gases upon the wheel and the other by the steam.

In this arrangement the expansion of the gases and the steam occur in parallel, so to speak, this being clearly indicated in the diagram. For constructive reasons, however, it is found convenient to adopt the previous system, the steam produced in the regenerator being delivered into the same nozzle as that used for the gases, and this plan has been adopted in our most recent turbine, even at some reduction in the thermal efficiency.

This machine, shown in several views, is of the same general type as the Curtis steam turbine, and is capable of delivering from 400 to 800 H. P., according to the compressor capacity utilized. The turbine is operated at 4000 revolutions per minute, and the speed regulation is

effected by a throttling valve in the air-admission pipe for small speed variations, and by a change in the fuel supply for larger changes, the regulating valves being controlled by a Hartung governor. There are three pumps attached to the machine,

which the water and steam circulate, the nozzles being of the expanding type similar to those of the De Laval steam turbine, although the expansion is completed in a shorter time. It is necessary that the expansion should be effected in a single

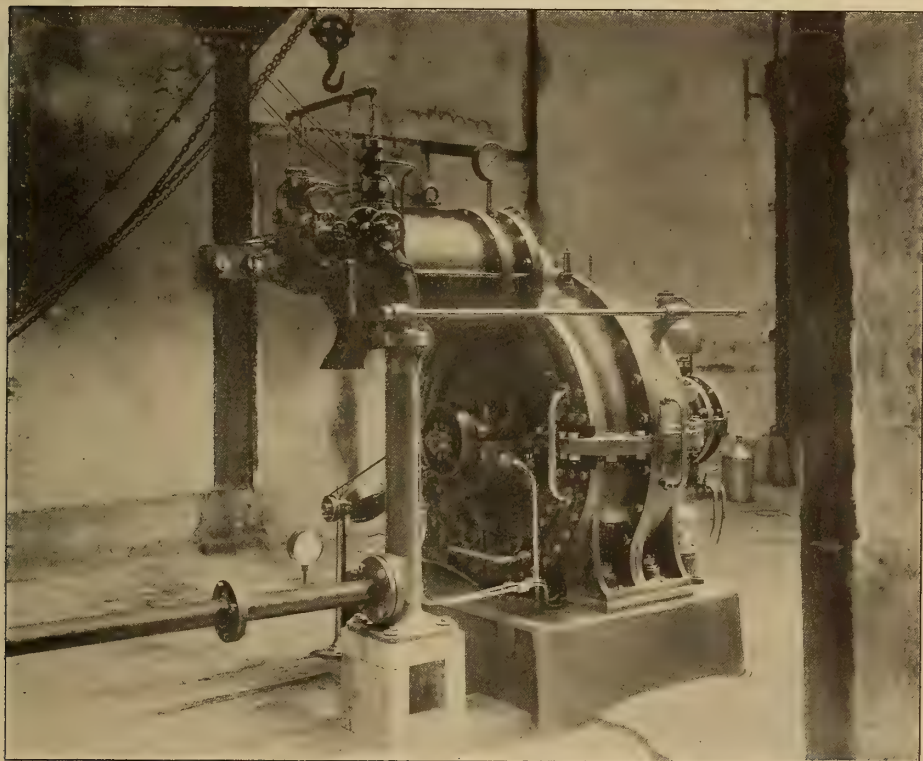


FIG. 10.—THE ARMENGAUD AND LEMALE GAS TURBINE

This view shows the combustion chamber, air and fuel inlets and connections

one the air compressor, another for the fuel supply, and the third for the water.

The combustion chamber is made of cast iron, lined with carborundum, the cast iron being protected with a water jacket. An elastic non-conducting lining is placed between the carborundum and the outer shell, this providing a bedding for the carborundum and also permitting a slight movement for differences in expansion and contraction. The extremity of the chamber and the nozzles are surrounded by a jacket space in

operation in order that the temperature should be sufficiently reduced before the gases reach the wheel.

The gasoline or other liquid fuel is delivered into the combustion chamber through a pulverizer, or atomizer, the construction of which is shown in Fig. 12. This is arranged with a reverse annular opening *B* delivering the fuel backward against the incoming stream of air, the angle causing the gasoline to form a sort of cone of minute particles, these becoming ignited as soon as their decreasing velocity permits. The pre-

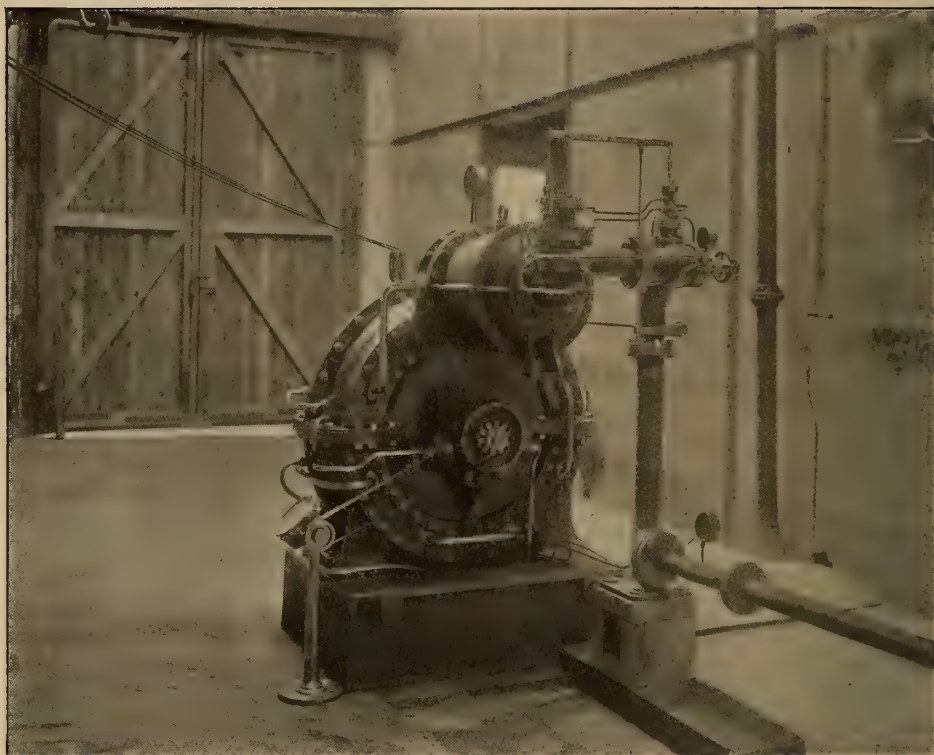


FIG. 11.—THE ARMENGAUD AND LEMALE GAS TURBINE

Another view of the combustion chamber, with air and fuel connections

heating of the fuel also renders the ignition easy. The atomizer is protected against the intense radiant heat of the chamber wall by the current of air with which it is continually surrounded. The igniting coil of platinum wire *D* is protected by a steel cap *C*, the electric current entering by the central insulated rod *E*, the circuit being completed through the machine itself. A pressure of 2 volts is found sufficient to render the platinum wire incandescent. The atomizer is inserted into the combustion chamber in such a manner that it can readily be removed for inspection and cleaning, this operation also giving complete access to the chamber itself.

The turbine wheel is arranged to be cooled by water circulation as shown in Fig. 13, this representing a section of the rim and a portion of

the disc. *A* and *B* are circular channels in the body of the rim, these being supplied with water by radial passages as at *E*. Small passages also permit the water to enter into each blade of the turbine and the difference in specific gravity between the hot and cold water is found to make an automatic circulation, in connection with the centrifugal force due to the high velocity of rotation.

The air supply for the turbine is furnished by a polycellular rotary compressor of the Rateau system. This important adjunct to the gas turbine, shown in Fig. 14, is composed of a number of turbine blowers arranged in series and especially designed to be operated at very high rotative speeds, so that it may be directly connected to the gas turbine.

The importance of the compressor is second only to that of the tur-

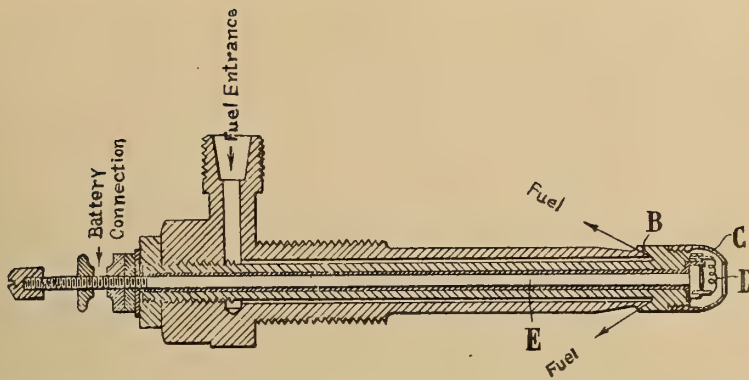


FIG. 12.—SECTION OF PULVERIZER AND IGNITER

bine itself, since it is of little value to possess a rotary combustion motor if a reciprocating compressor is a necessary auxiliary. It is on this ground, more than almost any other, that the design of a successful gas turbine has been considered problematical, and here, as in many other cases in the history of the development of a device, the progress of other departments of work becomes essential to complete success. The work of M. Rateau in the improvement of the steam turbine is well known, and by the application of the experience thus gained, a machine for the supply of compressed air to the gas turbine has been produced, involving only rotary motion, and thus capable of being driven directly by the turbine, and having an efficiency sufficiently high to permit a good performance of the combined apparatus.

The Rateau compressor is practically a reversal of the steam turbine, and is composed of a number of elements connected in series, so that the pressure is cumulative, the action being similar to that of the multiple centrifugal pumps which have been employed with such success for delivering water against high heads.

Each element of the compressor consists of two parts, the revolving wheel and the diffuser. The diffuser is arranged to provide discharge pas-

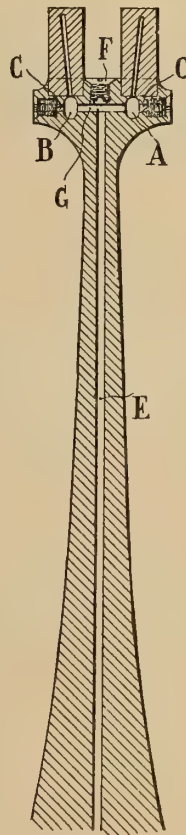


FIG. 13.—SECTION OF WHEEL OF GAS TURBINE, SHOWING PASSAGES FOR COOLING-WATER

sages for the air, having gradually increasing section for the flow, in order that the velocity of the air as

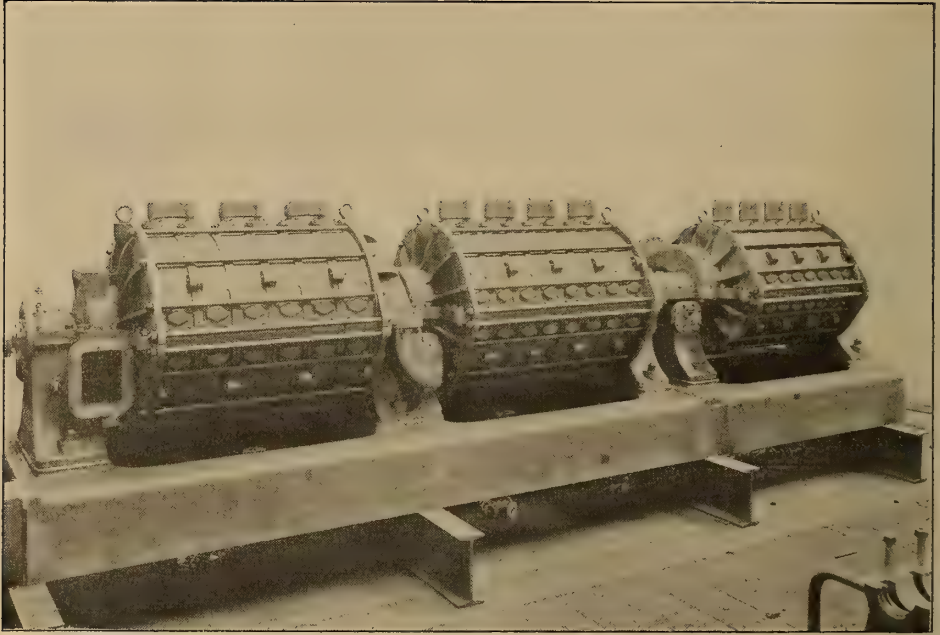


FIG. 14.—THE RATEAU POLYCELLULAR AIR COMPRESSOR

This multiple turbine blower furnishes air at more than 100 pounds pressure, with an efficiency of over 65 per cent., and is being used in connection with gas turbine researches.

it leaves the wheel may be reduced with the least possible loss, the kinetic energy being converted into pressure. The length of the machine is such that intermediate bearings have been introduced to provide support and stiffness to the rotating parts, and the whole design of the compressor has been so carefully worked out that an efficiency of 65 per cent. has been already attained, and present experiments indicate that this performance will be surpassed.

In Fig. 14 a Rateau compressor of three sections is shown, but larger machines have been constructed, and

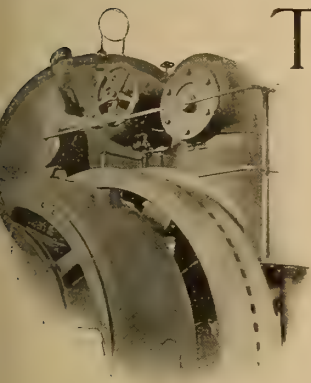
the pressures attained naturally depend upon the number of sections. Experiments have shown that in the first section the air is compressed to 1.7 kilogrammes per square centimeter, or about 24 pounds per square inch, absolute, the succeeding pressures being 2.9 kilogrammes, 4.9 kilogrammes, and 7.2 kilogrammes per square centimeter, the latter corresponding to 112 pounds per square inch above vacuum.

In a future article the efficiency of the gas turbine, of various makes and designs, will be discussed, from a theoretical and an experimental point.

LONG-DISTANCE POWER TRANSMISSION WITH DIRECT CURRENTS

By C. T. Wilkinson

The use of high-tension direct currents was proposed many years ago, a transmission at 14,000 volts over a distance of 120 kilometers having been installed as long ago as 1889. The method has been rather overshadowed by the wide introduction of the alternating current, but the successful operation of recent installations of the Thury system in Switzerland and elsewhere has called renewed attention to the possibilities and advantages of the direct current at high voltages. Mr. Wilkinson gives an authoritative and detailed account of the latest developments of the work of M. Thury, and his paper forms the latest and most complete description of a phase of electrical engineering of increasing importance and significance.—THE EDITOR.



THOSE who confronted the earliest problems of transmission will recall that at the first Niagara Convention the Hydraulic Commission which had under consideration the transmission of power from Niagara, awarded a gold medal to M. René

Thury for his continuous-current varying-voltage system.

At the present day there are no fewer than eighteen transmission plants in operation on this principle in Europe, representing a total of about 18,000 H. P., the constant current varying from 40 amperes in the case of the *Usines électricité d'Eisenburg* (Hungary), to 250 amperes for the Paris installation and from a maximum voltage of 1600 at Zug (Switzerland), to 60,000 for the latest transmission from Moutiers in Savoy to Lyons, and from 11 kilometers in the case of the Paris Company to 180 kilometers for the Lyons transmission.

The recent favorable decision of the Zambesi Commission and the purchase of the English patents by a prominent British company, have revived the interest in this system.

While in the opinion of many prominent European consulting engineers the Thury system has become a most powerful competition with the three-phase system for all long-distance transmissions.

The principle underlying the system is the employment of continuous current at a constant value and at a voltage varying in accordance with the energy demanded.

Many problems connected with the system must, therefore, be faced from a standpoint entirely the reverse of those common to three-phase alternating-current practice. Thus, a plant is spoken of as being designed for 75 amperes and 60,000 volts (Moutiers-Lyons transmission), but when first installed will operate at 75 amperes, and in the neighborhood of, say, 30,000 volts, the difference being held in reserve for an increase of load due to expansion of business with time. Further, to cut a high voltage generator out of the line in emergencies, it must be short-circuited, an open circuit being in all cases objectionable, since it tends to undue rise of voltage and in the constant-current system is guarded against by automatic devices wherever necessary.

The diagrams, Figs. 1 and 2, give a general comparative idea of the arrangement of the direct and the alternating-current systems, and show the simplicity of the continuous-current series system.

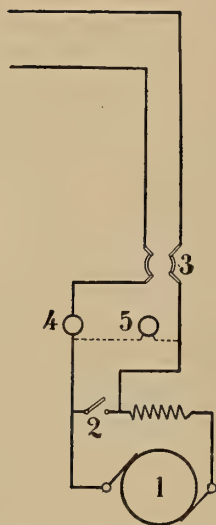


FIG. 1.—SCHEME OF APPARATUS FOR EACH GENERATING UNIT IN THE THURY CONTINUOUS-SERIES SYSTEM

1.—Generator. 2.—Reverse Rotation Automatic Cut-out Switch. 3.—Short-Circuiting Cut-out Switch. 4.—Ammeter. 5.—Voltmeter.

In this system the earth is in some cases employed as a return and conductor, but in the latest installations, for the reasons discussed later, it forms a neutral point and is used as an emergency return circuit, which can be employed in cases of repair, cleaning or overhauling of any part of the system without interruption of the service.

For this reason the insulation of the apparatus from the earth is of especial importance, and the manner in which this is accomplished in practice will be described hereafter.

In Fig. 3, the general arrangement of a typical Thury generating station is shown with the exception of the condenser, this showing the manner in which the machines are connected together in series, and displaying the principles underlying the system. Figs. 4 and 5 show the interior of the latest generating station yet erected, that at Moutiers, in Savoy, at which 5000 H. P. is developed and transmitted to Lyons, 180 kilometers distant, at a pressure of 60,000 volts.

The generators are placed in four

groups of four armatures, each armature developing 3700 volts, 75 amperes. Each group of four is driven by one hydraulic turbine, a friction insulated coupling being placed in the center of the four armatures and also between the turbine and the nearest generator.

The method of insulating the machines from the ground is also clearly shown. The cast-iron base of a semi-generating unit being supported on sixteen bolts, resting in cup insulators, each of which in turn fits into a second cup insulator suitably padded and embedded in the insulated flooring. In the latest practice this insulated flooring consists of an upper layer of pure asphalt and a second layer of asphalt and small stones mixed, the whole resting on a concrete foundation. It is interesting to

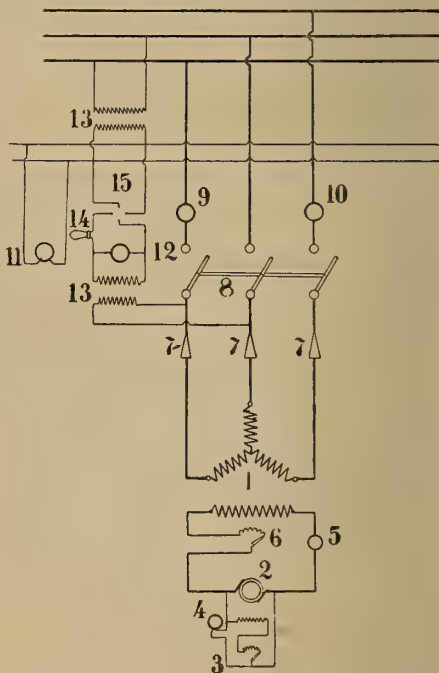


FIG. 2.—SCHEME OF APPARATUS FOR EACH GENERATING UNIT FOR THE THREE-PHASE ALTERNATING SYSTEM

1.—Generator. 2.—Exciter. 3.—Exciter Field Rheostat. 4.—Exciter Voltmeter. 5.—Exciter Ammeter. 6.—Alternator Field Rheostat. 7.—Generator Fuses. 8.—Generator Switch. 9.—Ammeter, Phase 1. 10.—Ammeter, Phase 2. 11 and 12.—Main-Line and Phasing Voltmeters. 13.—Phasing Transformers. 14.—Pilot Lamp. 15.—Four-Point Switch.

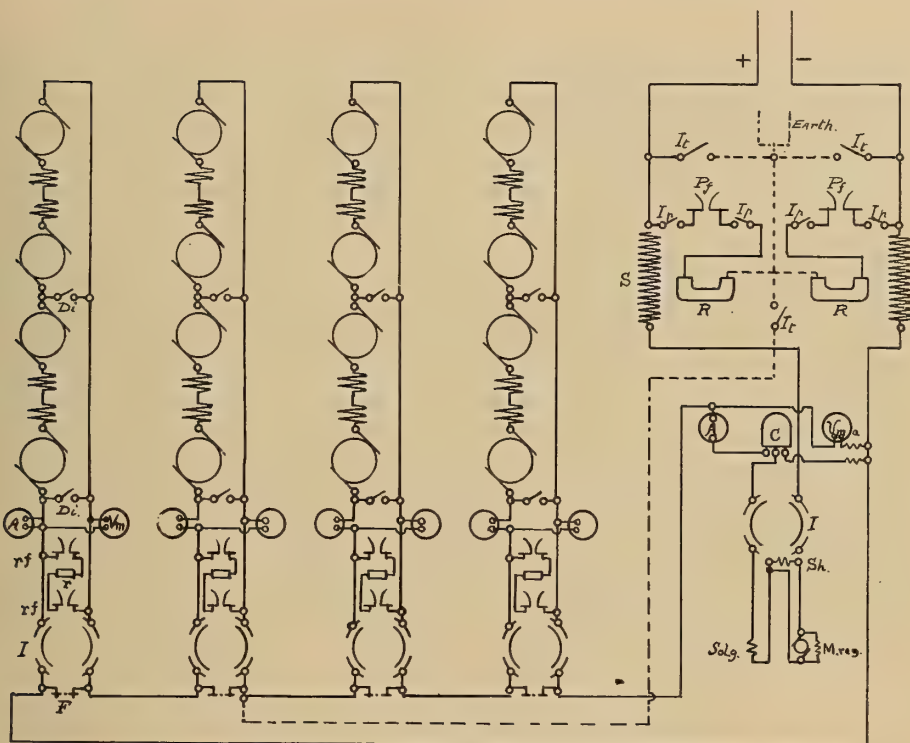


FIG. 3.—ARRANGEMENT OF A TYPICAL THURY GENERATING STATION

A.—Ammeter. C.—Wattmeter. Vm.—Machine Voltmeter. Vma.—Station Voltmeter. Sol. g.—Solenoid for Generator Regulator. M. reg.—Regulator Motor. Sh.—Regulator Shunt. F.—Safety Switch. Di.—Inverse Short-Circuiting Switch. Dv.—Excess-Speed Short-circuiting Switch. Ir.—Lightning Arrester Switch. It.—Earthing Switch. Pf.—Line Lightning Arrester. rf.—Machine Lightning Arrester. r.—Non-Inductive Resistance. R.—Water Resistance. S.—Choke Coils. I.—Short-circuiting Cut-out Switch

note that such a flooring having the upper layer 1 centimeter thick and the second $1\frac{1}{2}$ centimeters thick, is claimed to be capable of withstanding 80,000 volts alternating current. The generator leads are taken from the machines through terra cotta ducts embedded in the insulated flooring.

Figs. 6, 7 and 8 show the exterior and general interior arrangement of the St. Maurice generating station of the Commune de Lausanne, Switzerland, the arrangement of the apparatus being practically the same as shown in diagram in Fig. 3. This station is designed for a constant current of 150 amperes, and a maximum pressure of 22,500 volts. Each group consists of a turbine and two generators, the latter being designed for 150 amperes and 2250 volts, or 4500

volts per group at 300 revolutions per minute.

It will be seen, however, that M. Thury has discarded the method of mounting the ammeter and voltmeter on the top of the outside generator and the use of a small separate switch-post, as shown in Figs. 7 and 8, and now combines switches, meters and lightning arresters in one "Colonne de manœuvre," illustrated in Fig. 9. This last figure indicates clearly the method of insulating the switch handle, and shows that the whole post is mounted on the insulated flooring in the same way as the generators. The box immediately above the switch contains the voltmeter resistance, while on the top of all are mounted two horn-type lightning arresters with magnetic blow-out prongs,

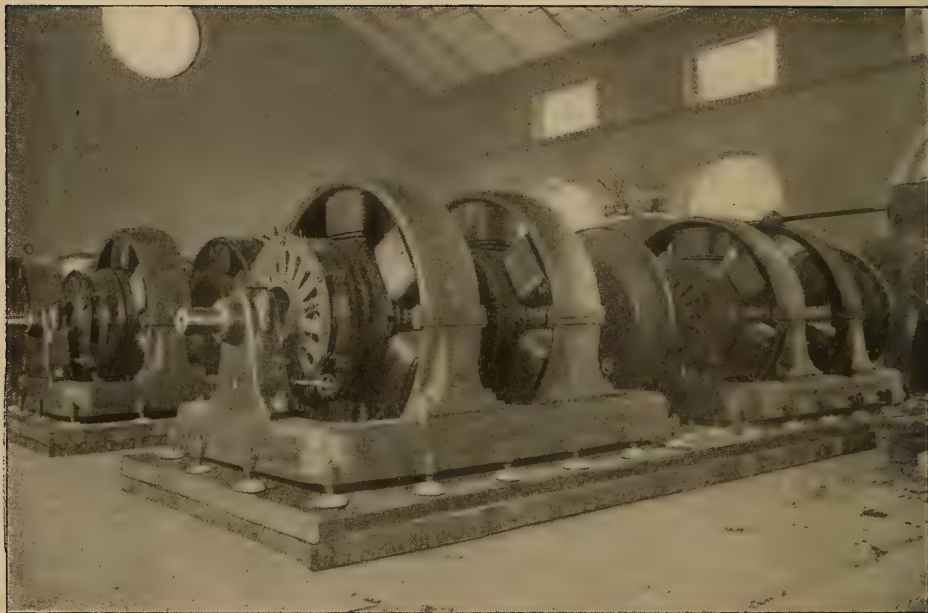


FIG. 4.—INTERIOR OF THE LATEST THURY GENERATING STATION AT MOUTIERS, SAVOY

Current is sent from thence to Lyons, 180 kilometers distant. The arrangement of generators and couplings is clearly shown



FIG. 5.—GENERAL VIEW OF INTERIOR OF GENERATING STATION AT MOUTIERS, SAVOY



FIG. 6.—EXTERIOR OF GENERATING STATION AT ST. MAURICE, SWITZERLAND

forming an effective protection.

It should also be noted that M. Thury has at last departed from the built-up style of frame previously connected with his name and adopted a standard round type, this change is stated to be for economic reasons.

The main station switchboard is very small and contains only a main ammeter, voltmeter and wattmeter and a main regulating switch.

In a modern plant for long-distance transmission, after leaving the generating station, the first point of interest is the earthing cabin.

The earthing system is of considerable importance. Reference to Fig. 3 shows that earthing switches are provided to enable either the neutral point or either line to be grounded. Fig. 10 shows the arrangement of an earthing cabin similar to those used on the latest 60,000-volt transmission, and in a line 180 kilometers in length there are two of these cabins provided.

The interior of these cabins contains two switchboards, each mounting two ammeters, one standard revolving four-point switch and two earthing switches, while one safety

switch is provided in each line. With this arrangement it is possible to operate with any section of either line grounded, and with either the positive, negative or neutral at the station grounded, thus safeguarding against any interruption which might occur in a long transmission line, due to local storms or any other mishap, breaking one line. In this connection the recent statement of Mons. M. A. Boissonnas, of Geneva, should be noted, that the use of the earth entirely for return wire on the Moutiers-Lyon system over the whole distance was not considered advisable, because of fear of telegraphic and telephonic disturbances.

The earth plates in these cabins consist simply of iron plates scattered over a small area and buried in wet earth wherever possible. In a recent example on a 75-ampere line, the voltage loss between earth and line was stated not to exceed 200 volts under the worst conditions, the maximum voltage for which the line was designed being 60,000.

Although the financial considerations involving the copper outlay and the line efficiency desired usually de-



FIG. 7.—INTERIOR OF ST. MAURICE STATION

termine the size of the conductor, it is claimed that a reasonable line loss is not undesirable from the point of view of regulation and the prevention of sudden fluctuations, though in all cases it is easy to obtain a wonderfully high efficiency, as will be shown hereafter.

Where it is desired to employ an earth return, it is, perhaps, desirable that some arrangement should be made for more than one earthing point at each end. Even if cheap scrap iron in any form is employed, calculations indicate that one ampere flowing for one week will deteriorate one cubic inch of wrought iron.

The interior of a typical receiving station is shown in Fig. 11, which represents Usine de la Rue d'Alsace, Lyons. This shows the station with two sets already installed. The insulated flooring and cup insulators are

again clearly to be seen, and are the same as in the generating station. The motor-generator set in the foreground consists of one Thury motor group provided with two separate armatures, each rated 400 horsepower, 3900 volts. This group is connected through a flexible insulating coupling to a 600-volt traction generator.

Fig. 12 shows the control post for one of the above groups, this post mounting an ammeter, a voltmeter and one lightning arrester. The arrester, however, will shortly be removed, as the transmission into this station by underground cable for some distance and lightning protection is found unnecessary.

The ebonite case in front of the resistance box contains a carbon brake operated mechanically from the main switch and used when breaking a short circuit of a direct-current armature, the high induction of which produces a noticeable arc.

Directly above the tachometer, Fig. 11, is a small ebonite box containing an automatic short-circuiting cut-out switch arranged to operate in case of reverse rotation.

In the receiving station, in addition, there is mounted behind the "Colonne de Manœuvre" an over voltage cut-out switch operating in connection with the voltmeter resistance in the case to which it is attached and serving to prevent undue overload of the motor.

The arrangement of a Thury receiving station is otherwise similar to that for the generating station, except for the governors, which here control for constant speed.

The control of the whole system is, to some extent, dependent upon regulators, but the day of the old pivoted switch, varying the number of turns of the field coils with its attendant troubles, is past, and the regulator is now greatly simplified.

At the generator end, the gover-

nor, Fig. 13, operates to maintain a constant current of definite value by means of a solenoid in series with the line. Any variation from this normal value, up or down, causes a corresponding movement of the armature of the solenoid. This motion is transmitted by means of a system of ratchets and toothed wheels to the

small motor. It is of interest to note that the switchboard and regulator are all in series on one side of the line, and that the voltage drop does not exceed from three to six volts. The regulator apparatus is mounted upon an insulated post similar to those shown in Figs. 9 and 12.

The regulator at the receiving sta-

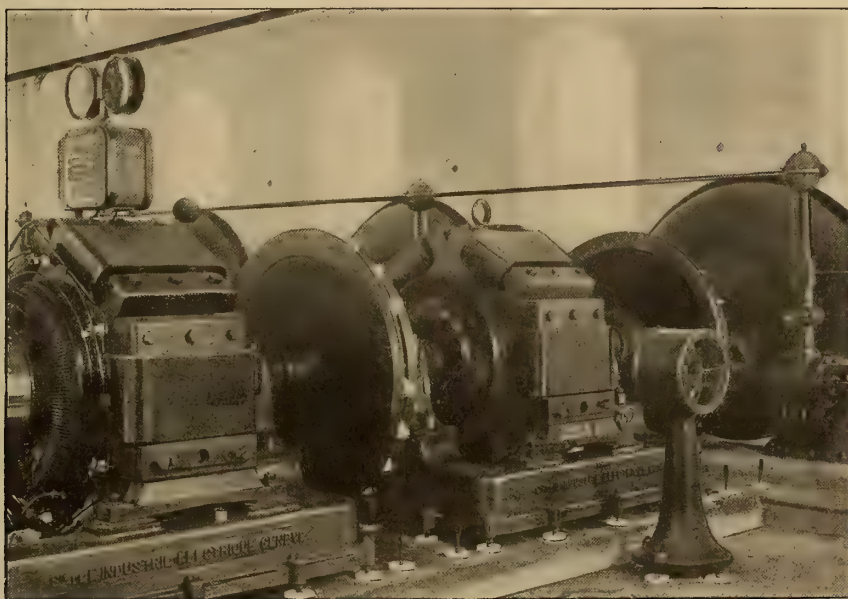


FIG. 8.—INTERIOR OF STATION AT ST MAURICE

Showing turbine and two generators, the group being rated 150 amperes, 4500 volts, 300 revolutions
The controller is also shown.

governor shafting which operates hydraulic pilot valves, which, in turn, work the main turbine gates, varying the speed of the sets according to the voltage demanded.

The ratchets just referred to are kept in motion by a small motor in series with the line (see Fig. 3). It should be noted that the full current does not pass through the armature, the motor being shunted by a permanent resistance and also by a secondary battery which serves to maintain operation in case of interruption of the main circuit. This battery consists of only two or three elements, depending upon whether copper or carbon brushes are employed on the

tion, Fig. 14, is provided to maintain the speed of the motor-generator sets constant. This regulator consists of an ordinary centrifugal ball-type governor arranged to hold the speed constant by varying the position of the commutator brushes over the voltage angle in accordance with the torque demanded.

Thus, when a Thury motor is first thrown into the circuit, the brushes are in the neutral, no-voltage, no-torque position, and when loaded the torque is roughly proportional to the displacement from this neutral, the maximum displacement being 90 electrical degrees either clockwise or counterclockwise, according to the

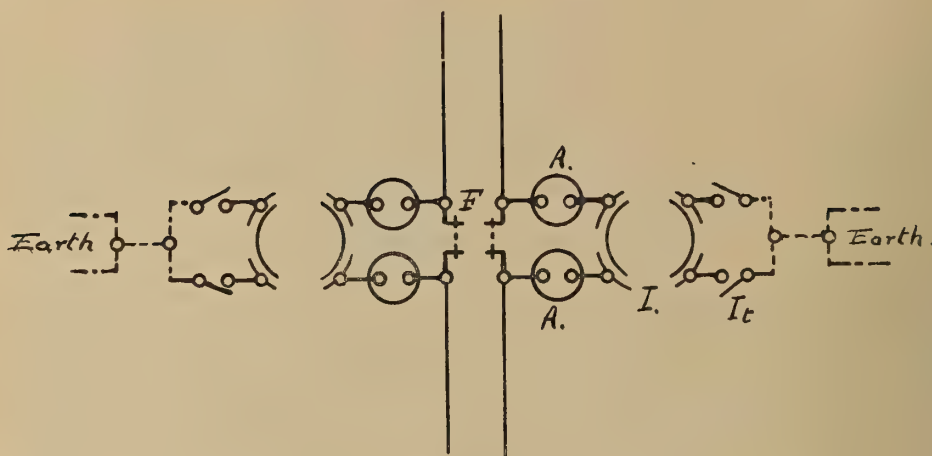


FIG. 10.—GENERAL ARRANGEMENT OF EARTHING CABIN

A.—Ammeter. F.—Safety and Meter Switch. I.—Revolving-type Switch. It.—Earthing Switch

direction of rotation which is desired.

The regulators at intermediate stations, if these stations are capable of reverse operation, are supplied with a regulator containing the essential features of both the above. One of these is illustrated in Fig. 15, the brushes being operated through the geared wheels shown.

Where several stations are connected in series, power being taken from each, it is sometimes arranged so that the regulation is all done at one station, the remainder running on dead-load, this method being employed by the Société Acquadotto Ferrari-Galliera, Genoa, Italy.

The special advantages of the continuous current over the alternating system are claimed to be as follows:—

First.—The enormous economy in transmission-line material and switchboards. Recent data show that on a line 95 miles long, the saving in transmission copper, poles, insulators, lightning arresters, etc., was estimated to exceed 50 per cent., where the direct-current voltage was 150,000 (grounded neutral) and the alternating-current, three-phase voltage 60,000, the line efficiency being 95 per cent. approximately for the continuous current and 91 per cent. for the alternating current, calculated

values on the same comparative basis.

Second.—The switching arrangements consist of one revolving switch placed on a post mounting the apparatus shown in Figs. 9 and 12, and one of these is required for each group of generators, and in addition for the whole station only one other main station switch. This is claimed to lead to extreme simplicity in operation and some economy and saving in the number of operators.

Third.—Rather exceptional freedom from lightning troubles is claimed, and it is pointed out that this is obtained by the use of a large inductance at each end of the line, the usual horn arresters and resistance with spark gaps for atmospheric discharge, while inside of all this a large condenser is placed, having the effect of absorbing any high peak of voltage which may pass the other somewhat standard devices.

Fourth.—Freedom from mutual induction troubles is also obtained, static or capacity discharge considerably reduced, the distance apart of the wires becoming solely a question of brush discharge.

At present this system has not been used for transmitting more than 5000 KW., but the favourable consideration of the Zambesi Commission



FIG. 9.—CONTROLLER STANDARD FOR A FOUR-UNIT GENERATOR

shows that M. Thury has succeeded in creating a favourable impression with regard to his ability to transmit large quantities of energy by this method.

A point of great importance in this system is the possibility of adapting it with considerable economy in first cost to the problems of power supply to a large city from the outside. Only two cables have to be run from the power station into the city, these being divided shortly after entering into a loop correctly placed geometrically with regard to the load distribution and having series sub-stations tapped in at any desired point. Not only is this a saving from the point of view of the number of cables, but also of their first cost, since the insulation strain is found to be considerably less than the ratio of 1 to 0.707 and a cheaper cable may be

employed if it is thought desirable.

Dangers from short-circuiting of generators are provided against not only by one or two friction couplings, but also from considerations of the torque curve of the turbine and the series design of the generators.

Should unforeseen load conditions arise, by which it is desirable to raise the energy transmitted beyond the designed voltage limit, the two armatures which form a semi-generating group and are placed on a common shaft may be connected in multiple, thus doubling the current, while additional machinery may be installed to bring the voltage up to normal.

A short-circuit test conducted at the St. Maurice station (Commune de Lausanne system,—22,500 volts maximum), where the generators are designed for a normal current of

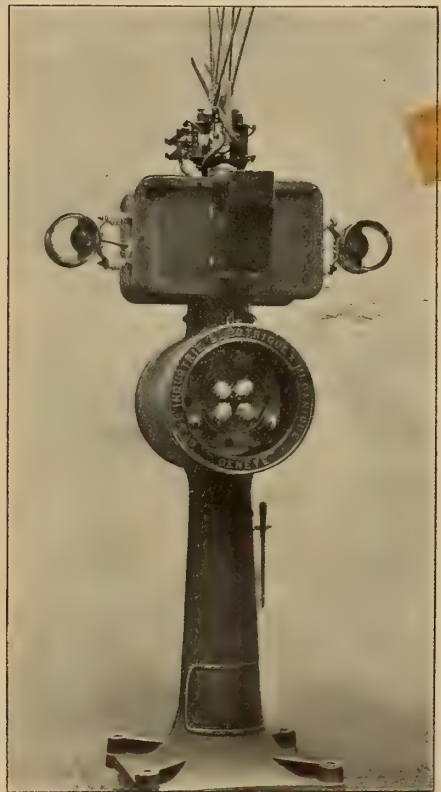


FIG. 12.—CONTROLLER STANDARD FOR TWO-UNIT MOTOR GROUP OF 720 HORSE-POWER

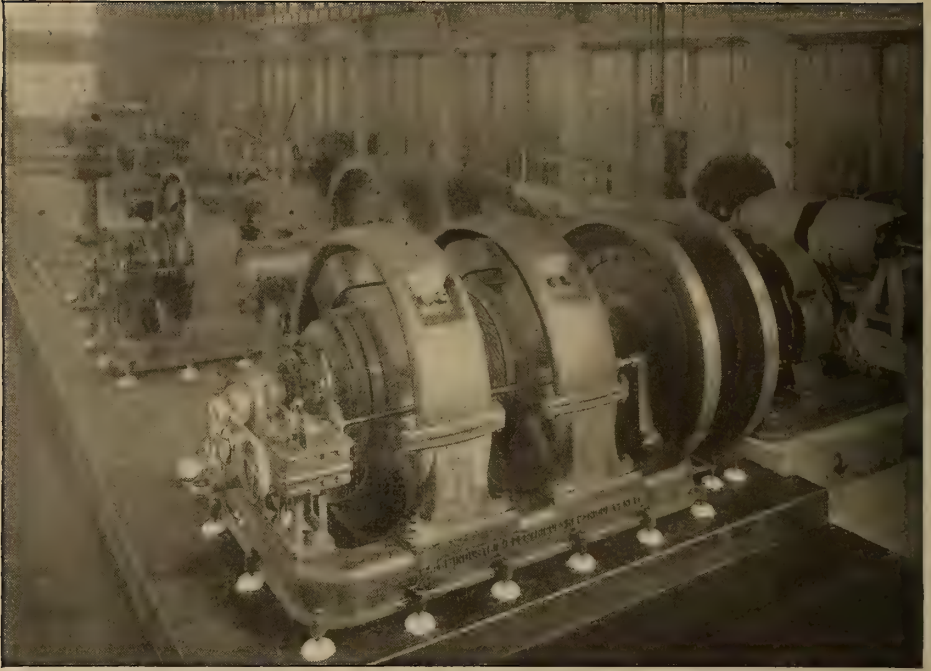


FIG. 11.—INTERIOR OF RECEIVING STATION AT LYONS

Current is received here from Moutiers, the generating station shown in Fig. 4

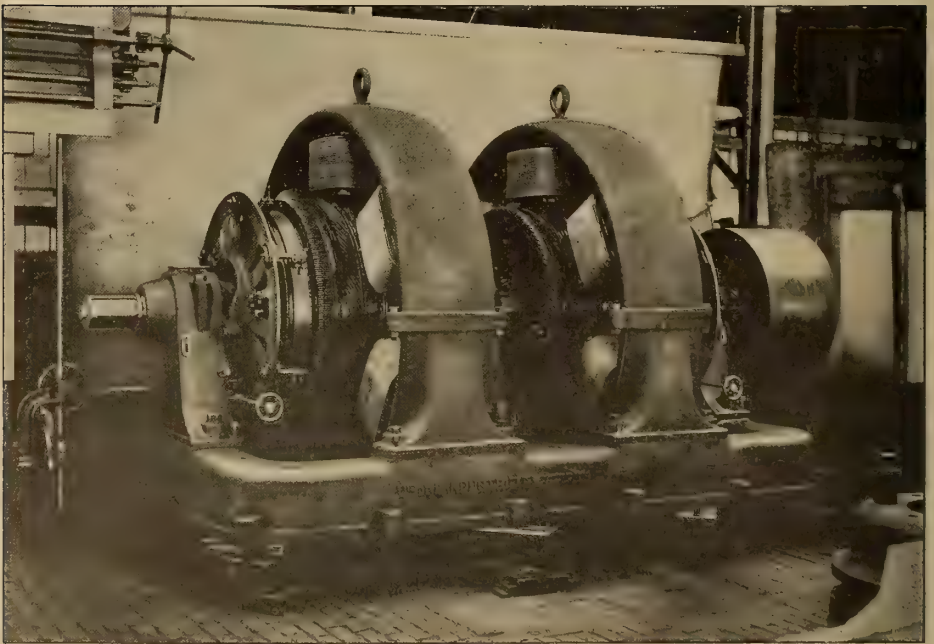


FIG. 16.—A TWO-UNIT GROUP ERECTED FOR TEST IN THE FACTORY

Designed for 7,200 volts per group, 75 amperes, 300 revolutions, 540 kilowatts

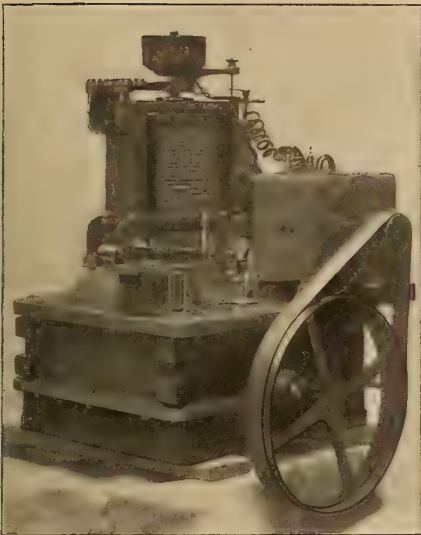


FIG. 13.—AUTOMATIC REGULATOR TO HOLD CURRENT AT CONSTANT VALUE AT GENERATING STATION

150 amperes, is said to have led to a rise of current to 250 amperes, or less than twice normal, while the action of the regulators reducing the voltage, and thus the current to normal value, was considered in every way perfect.

In the United States statements are sometimes made with regard to supposed insulation troubles, but an examination of the published dimensions of line insulators and cable insulation and the knowledge of the voltages these are called upon to withstand, should serve to satisfy all reasonable doubt.

The simplicity of operation of this system is illustrated by the ease with which a group can be thrown in or out of circuit; thus, suppose additional load makes it necessary to put another group in series with the line. The vertical controlling rod operating the oil pilot valves at each turbine (see Figs. 4, 5, and 7) is moved by hand and the set slowly revolves, still, however, short-circuited on itself. At about six revolutions per minute the voltage produced is sufficient to cause full-load current to circulate in the short-circuited machine, and directly this is obtained

the switch is rotated and the machine placed in series with the line.

More water is admitted to the turbine until the group carries its share of the load, when the hand wheel is locked with the main governor shafting, which controls all the groups.

In the case of a short circuit of a generating group, it is claimed that the current cannot become excessive and does not rise much above twice normal value. The explanation is as follows:—

The torque increases as the square of the current, and the design of the turbine only permits it to develop twice normal torque, hence the set will rapidly drop in speed.

In addition, two friction couplings are provided, which are suitably adjusted to prevent undue strains.

On the most recent system installed by the Compagnie de l'Industrie Electrique et Mécanique, Geneva, the generators, where they have no other function to perform, have their voltage controlled by change of speed in the method already described, but where they have to act either as motors or generators they are designed fundamentally like the

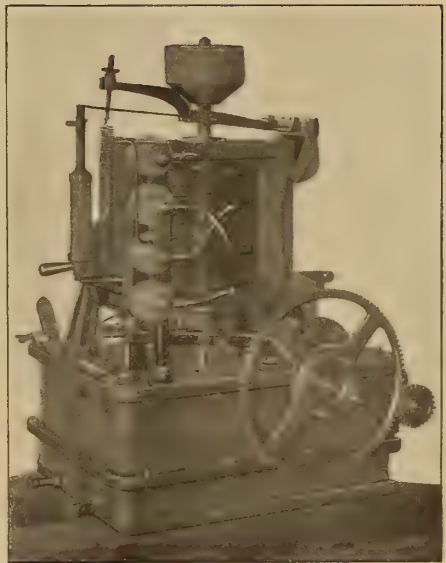


FIG. 15.—COMBINED REGULATOR, USED WHEN MACHINE IS EITHER GENERATOR OR MOTOR

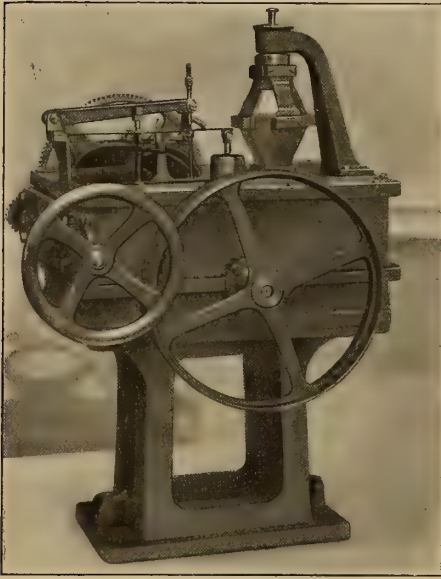


FIG. 14.—REGULATOR AT RECEIVING STATION, HOLDING MOTORS AT CONSTANT SPEED

motors, and the voltage is varied by variation in the position of the brushes on the commutator, the change in voltage then taking place by the variation in the number of armature conductors which oppose the field flux, the machines all being series-wound.

The commutation on all these machines is excellent, and no trouble whatever from sparking is apparent under the entire range of load.

As some indication of the fact that the transmission of electrical energy over long distances by high-tension

direct currents is not a new thing, but that it has been in practical service for a number of years, it is desirable that some of the more important installations should be mentioned. Thus, as long ago as 1889 the plant of the Société Acquedotto Ferrari-Galleria was installed, at Genoa, operating over a distance of 120 kilometres, and transmitting 1260 horse-power at a pressure of 14,000 volts. Since 1893 the Compagnie Parisienne de l'Air Comprimé, better known as the Popp Company, of Paris, has used the system for transmitting 1200 horse-power at 3500 volts. At Brescia, in Italy, the Société d'Eclairage Electrique is using this method, at 10,500 volts, for 850 horse-power, this plant dating from 1895; and another installation of the same date is that of the Société des Forces Motrices de la Grande Eau, at Aigle, in Switzerland, this latter plant being operated at 14,000 volts. The plant of the Commune de Lausanne has already been mentioned, this having been installed in 1902, while the latest installation, as has been said, is the Moutiers-Lyons plant, completed in 1906.

Already there is discussion of still larger applications of the Thury system, the principal of these being the proposed Rhone-Paris transmission, this involving the use of the direct current at a pressure of 120,000 volts, over a distance of 250 miles, and a capacity of about 80,000 horse-power.

THE PRODUCTION OF MALLEABLE CASTINGS AND THEIR APPLICATION IN MACHINE CONSTRUCTION

By Dr. Richard Moldenke

The convenience of malleable cast iron as a material of construction is generally appreciated, but it is also recognized that the material should be employed with judgment and that proper skill and knowledge be used in the production of such castings. The designing engineer and the foundryman should work hand in hand, bringing to their aid the best scientific knowledge and practical experience available, and under such conditions malleable cast iron has many applications. Dr. Moldenke is familiar with foundry practice on both sides of the Atlantic, and, although he speaks mainly of practice in the United States, the conditions are not greatly different all over the world, and his discussion may be accepted as authoritative.—The Editor.

AMONG the many ramifications of the iron industry the branch which relates to the preparation of malleable cast iron occupies a very unique position. That an industry which depends solely upon the heat treatment of irons of the proper composition should have grown to an enormous annual tonnage shows how well it must serve the demands for quality, price, and ease in production. Over 650,000 tons of malleable castings is the annual product of America or more than ten times the entire output of Europe, where, however, the conditions under which malleable castings are made and used are not the same as in the United States.

Considering the fact that a well-made malleable casting has two-thirds the strength of a steel one, is over twice as strong as a plain gray iron casting, and in shock-resisting power exceeds them both, it would seem desirable to go somewhat into the characteristics of a material which is used to so great an extent, very few of the purchasers being able to distinguish a good from a poor iron, and, for that matter, very few makers, either.

The production of malleable castings was first described by Réaumur, in 1722, and such has been the secrecy and ignorance involved that up to fifteen years ago nothing more was known generally about the pro-

cess than was published so long ago, and likely carried on long before that time in a small way. The production of malleable cast iron is now an exact science for those who know; and yet even with the knowledge gained, this consisting practically only of the chemical limits of composition and limits of the annealing temperature, no further improvement in the process has been made. Going beyond the limits of composition in the hard casting makes it impossible to get any results from the heat treatment, and, varying this, disappointment is sure to follow.

When properly made, malleable cast iron should have a tensile strength of 42,000 to 48,000 pounds per square inch, with an elongation of 5 per cent. in 2 inches. Bars 1 inch square and on supports 12 inches apart should show a transverse strength of 2500 to 3500 pounds, with a deflection of at least $\frac{1}{2}$ inch. The resilience should be at least eight times that of cast iron. Malleable cast iron can be bent, twisted, and abused very much before giving way, thus making the material ideal for service where a fair tensile strength is required, but especially where often repeated shocks are the rule. The use of this class of iron is, of course, limited by conditions of size, weight, and thickness, which will be discussed later on. In the early history of the M. C. B. coupler numer-

ous tests were made by the drop weight of standard dimensions on malleable cast-iron couplers, as well as those made of cast steel. The latter had a much higher tensile strength, but when it came to a number of drops of the hammer, the malleable couplers usually came out best. In actual service also it was found that the continual battering of the heads would weaken the crystal-line structure of the steel throughout, while a malleable cast-iron coupler might be mashed flat by this same battering action, and yet have the sound portions of the casting of the original strength. No wonder that the railroad interests were loth to drop the malleable cast-iron coupler for the steel one, when the very heavy steel cars made this a necessity on account of the high pulling strains involved.

While the strength of malleable cast iron should be as given above, much of it will fall as low as 35,000 pounds per square inch, and this will still be good for such work as pipe fittings, hardware castings, and the like, where a certain amount of punishment can be expected and cracking should not take place. On the other hand, this material can be made exceedingly strong, even 63,000 pounds per square inch having been reached, as well as a deflection of $2\frac{1}{2}$ inches on the transverse test, with oftentimes 5000 pounds to cause rupture. This, however, is not desirable, as the softness of the casting is sacrificed in this way, and its resistance to continued shock lessened.

The process of making malleable cast iron may be briefly summarized as follows:—The proper irons are melted in either the crucible, the air furnace, the open hearth furnace, or the cupola. The metal when cast into the sand moulds must chill white or not more than just a little mottled. After rolling off the sand from the hard castings, they go into the annealing department, where they are packed in puddle scale, or other

materials containing iron oxide, and here subjected to a period of red heat, over sixty hours after reaching the proper temperature. They are then cooled gradually, rolled again to remove adhering scale, chipped or ground, straightened, and shipped away. This looks exceedingly simple, but there are involved so many little points in detail that a small fortune can be lost very quickly in a large establishment by inattention on the part of the employees. A few of these things will be explained here, as they have a bearing on the value of the work subsequently.

First of all the composition of the casting itself. When hard, or just from the sand, the iron should be about as follows:—Silicon, from 0.35 up to 1.00, depending upon the thickness and the purpose the casting is to be used for. Phosphorus had better not go over 0.225, manganese not over 0.20, sulphur not over 0.05 in American practice, but can be pretty nearly anything in European, judging from samples analyzed; their process, however, being a much longer anneal of the very light castings, allows this. The total carbon can be from 2.75 upward, 4.15 being about the highest that can be carried. The lower the carbon the stronger the casting subsequently. Below 2.75 there is apt to be trouble in the anneal, the nice black-heart structure may not appear, and the castings remain weak. To get this low carbon it is necessary to add steel scrap to the mixture rather than to attempt a refining of the metal in the bath, or, worse yet, to buy very low carbon pig-irons. The silicon, which was stated to run between 0.35 and 1.000, has the following bearing. In order to get the carbon all into the combined state in the casting in the sand, it is necessary to drop the silicon to a point which will just do this. Hence a casting 1 inch thick would necessitate a silicon at the lowest limit given, and the use of chills in the mould in addition, to get the iron white. For a casting half an

inch thick, the silicon at about 0.60 would just do the trick. Hence for such work this is the proper limit, except where great strength is desired, when the silicon can be dropped to 0.45. Above 0.60, however, there is danger of getting heavily mottled if not gray iron from the sand moulds, and this material, when put into the anneal for the long time required for the white castings, would be ruined. For very thin castings, similarly, the silicon can run up to 1.00 and still leave the metal white in fracture. Thus it will be seen that the composition, so far as the fracture shown by the condition of the carbon is concerned, depends upon the thickness of the section. The silicon regulates the carbon right when properly calculated for the thickness. Furthermore, there is involved the rate of cooling of the iron, also a function of the thickness, and finally the temperature of the metal poured. It would carry us too far to go into these niceties, but it will be readily seen that a very exact balancing of conditions is required to make malleable cast iron successfully, and ignorance, though not excusable, is naturally prevalent. Indeed, it is not so long ago that a well-meaning brother foundryman wished to know who that "feller Silicon" was, of whom he had read so much of recent years.

The bearing of the above questions of composition upon the castings delivered to the consumer is as follows:—The malleabilization process being in effect simply a conversion of the combined carbon of the hard casting to the amorphous uncombined carbon of the annealed casting, the mere fact that this conversion has taken place shows that the composition must have been correct. Important castings should, therefore, have left on them small test plugs of the thickness of the heaviest part of the casting, which can be broken off by the buyer, so that he can assure himself that the casting is good, for an unannealed as well as a gray

casting from the anneal is worse than ordinary cast iron for strength.

While the casting may be of proper composition, as shown by the test plug, yet it may not be of high strength. This can only be determined by having test bars cast from the same heat and annealed with the work. The founder can get varying degrees of strength in his castings of exactly the same composition by changing his mixtures and process of melting. Thus the ordinary method is to use half pig-iron and half scrap for the melt. It may happen that the particular foundry makes very heavy work, and has less scrap than another where the lightest castings are made, and where the sprues of the day exceed the castings turned out. Here special precautions must be taken to utilize the scrap made, or to make up additional strength by adding steel and even annealed malleable cast-iron scrap. Complications are apt to set in here, and a malleable cast iron foundry when the mixture is giving trouble is a very anxious place, for the result cannot be known until the anneal shows it a week later, and in the meantime a week's work may be worthless before it is found out.

Again, the melting method has much to do with results. The crucible is too expensive, and hence is passing away, though it made most excellent work. The cupola makes the worst iron, as the metal and fuel are in contact. Cupola iron should never be used for important castings on that account. Furthermore, this iron requires a higher annealing temperature, and the work suffers correspondingly. In the market it sells at a lower figure. For small work cupola iron gives passable results, and has its place in the industry.

Air furnace castings, and, better still, open hearth castings, give the most desirable product, and this should be called for when uniformly strong castings are wanted. The majority of foundries making these castings are equipped with the air

furnace, and hence no difficulty should be experienced in placing orders.

Many attempts have been made to shorten the period of annealing. That this is possible is well known,—the higher the temperature the quicker the conversion of the carbon. However, experience has shown that this conversion, delicate enough in the old long-continued, low-temperature process, is much more uncertain when a high heat is used, there being a tendency to a return to the combined form on the part of the carbon when the process is disturbed in any way. Even a good annealed casting, if warped badly, must be straightened cold, otherwise on heating and hammering it is liable to go back to the white state, and consequently break in service. All attempts to use the higher and shorter annealing heat have met with disaster financially, and hence the regular process, perhaps shortened a day when absolutely necessary, is adhered to. The temperature of annealing furnace iron castings is between 1250 and 1350 degrees F., the temperature being taken by pyrometer at the coldest spot in the coldest part of the annealing oven. The pyrometer must take the temperature of the annealing pot, and not the gases of the oven, as these are several hundred degrees higher.

The question of annealing is an interesting one. A short heating to the proper temperature on the part of a hard gray iron casting softens it sufficiently to allow machining. This is the conversion of the comparatively small amount of combined carbon present over the normal figure to the "temper" carbon of the malleable casting. This "temper" carbon, so named by the late Prof. Ledebur from "Temperguss," the German for malleable cast iron, is an uncrystallized graphite which has the peculiar property of recombining at a temperature below the melting point. Thus heating an annealed casting red hot and plunging into water usually

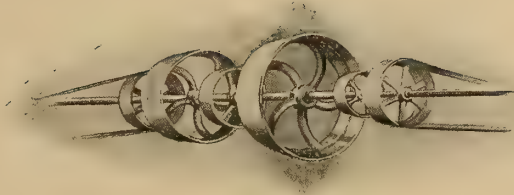
makes its structure white again, but this structure is now that of a high carbon steel rather than a white iron. While, therefore, this short annealing of a hard gray casting does it good, the continued heat of the malleable casting process applied to the same casting would ruin it, by allowing the penetration of oxygen, burning, or at least oxydizing, each crystal of iron, separated, as they are, by the flakes of graphite in the gray casting. Hence the necessity of keeping out graphite from the hard casting intended for the malleable anneal.

The annealing process is further interesting from the fact that only the conversion of the carbon is a necessity to make malleable cast iron, and not the removal of the carbon from the skin, which is the understanding generally. While this removal of the carbon in the skin does take place in the ordinary process where an iron oxide is used for packing the castings into the annealing pots, yet by doing this in sand or in fire clay the same results are obtained, the only difference being a smaller tensile strength. As the flakes dropping from the annealing pots can be crushed and used for the packing medium, there is no necessity to resort to annealing in sand in order to save money, especially as a weaker casting is the result. Experiments made with numerous test bars, the skin of which had been removed from half their length, showed that the black interior of a malleable casting having the original amount of carbon intact, though converted from the combined state, is but 2000 to 3000 pounds per square inch less in tensile strength than the bar with the skin left on.

The founder has to deal with many moulding problems also, for the contraction of the hard casting is twice that of a soft gray one. The annealing process restores half of this shortening up in length, breadth and thickness, but the consequence is that very large castings are difficult, if

not impossible, to make without concealed cracks occurring where least wanted. Furthermore, the internal shrinkage of the metal is a serious question, taking place at abrupt changes of section and sharp angles. Hence the use of chills in the moulds to overcome this difficulty. On the whole, therefore, the malleable casting is seldom over 175 pounds in weight, or 3 feet in length, or three-quarters of an inch in thickness. The great majority of even the heavier castings do not exceed ten pounds, and when it is considered

that some establishments are making eighty tons of castings daily, averaging this weight, the number of men required running over the thousand mark, it will be seen that a large plant involves an enormous outlay of capital and an equally enormous risk. In spite of this, the future of the industry is a bright one, for the malleable casting holds its own against steel and gray iron, the only requirement being that the demands of the engineer upon it must fit with characteristics of the material.



THE STEAM LOCOMOTIVE OF THE FUTURE

By Lawford H. Fry



POSSIBLY in the far future the electric locomotive may completely supersede the steam locomotive, but so much capital is involved in this change that the steam locomotive will certainly have to be reckoned with for many years to come. In the present article I do not propose to attempt long-range prophesy, but to gain by an analysis of present practice some knowledge of the lines along which the steam locomotive will develop in

the future. It will be found, I think, that a reasonable knowledge of the future can be obtained from a study of the accepted types of the present day, and from a consideration of the fundamental principles which govern locomotive design.

Viewed from a strictly elemental standpoint a locomotive is a machine for imparting velocity to a train. The steam locomotive uses the potential energy of coal or other fuel in the production of the impelling or tractive force required to overcome the resistance of the train. In this transformation of energy there are four distinct processes:—

- 1.—Combustion of the fuel.
- 2.—Production of the steam.
- 3.—Utilization of the steam.
- 4.—Impulsion by the adhesion of the driving wheels.

A brief study of the general principles involved in each of these pro-

cesses is necessary to the present purpose.

I.—COMBUSTION OF THE FUEL

Coal and oil are the two most important locomotive fuels. Weight for weight, oil is nearly twice as efficient as coal, but in the majority of localities coal is less than half the price of oil, and is therefore the most economical fuel. To obtain the most efficient results with coal, it must be burned at the proper rate, which will depend on the quality of the coal. If the rate of combustion is too low, there are likely to be losses from excess air and lack of efficient combustion by reason of the fire-box temperature being too low. If the rate of combustion is too high, the draught will carry off a large percentage of the smaller coal unburnt.

For our present investigation we shall not go far wrong if we put the desirable rate of combustion of bituminous coal at from 100 to 120 pounds of coal per square foot of grate per hour. Thus, if it is necessary for the service conditions for which the locomotive is designed to burn 3600 pounds of coal per hour, the grate should have an area of from 30 to 36 square feet.

2.—PRODUCTION OF THE STEAM

Part of the heat produced by the combustion is transferred by radiation from the fire and by convection of the heated products of combustion of the heating surface, and being thus given up to the water, steam is produced. A boiler of the regular locomotive type will absorb heat at a rate sufficient to evaporate from 12 to 15 pounds of water, from and at 212 degrees F. per hour for each square foot of total heating surface.



FIG. 1.—SINGLE-EXPANSION ATLANTIC TYPE LOCOMOTIVE. BUILT FOR THE CHICAGO & ALTON RAILWAY
BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA

Cylinders—Diameter.....	20 inches	Heating surface—Tubes.....	3056 square feet
Stroke.....	28 inches	Firebox.....	191 square feet
Driving wheel diameter.....	80 inches	Total.....	3247 square feet
Boiler pressure.....	200 pounds square inch	Grate area.....	54.2 square feet
Weight in service—On driving wheels.....	103700 pounds		
Total locomotive.....	183,800 pounds		
Weight of locomotive with half loaded tender..	310,000 pounds		

There is little definite information as to the rate at which the heat transfer takes place at different parts of the heating surface, but it is certain that the evaporation from the fire-box heating surface, and from the ends of the tubes near the fire-box is much greater than the evaporation at the smoke-box ends of the tubes, where the products of combustion are at a lower temperature than they are in the fire-box. Probably the rate of evaporation from the hottest parts of the heating surface is ten times the average rate of evaporation for the whole surface, but there are not sufficient experimental data on record to establish exact figures for this relation.

Generally speaking, it is desirable in a locomotive boiler for soft coal to make the area of the total heating surface about sixty-five times the area of the grate. This will give enough heating surface to absorb, with proper efficiency, the heat produced at the grate by combustion. If the heating surface is much less than sixty-five times the grate area, more heat will be produced at the grate than can be

transferred to the water, and the boiler will lose in efficiency. On the other hand, if the heating surface is made much more than sixty-five times the grate area, the increase in heat-absorbing capacity will, in most cases, be so slight that the increase in boiler efficiency will not compensate for the increase in weight which is involved.

UTILIZATION OF THE STEAM

As the steam is expanded in the cylinders, part of the heat energy which was communicated to it through the heating surface is transformed into mechanical work, which appears in the rotation of the driving wheels.

To perform this operation efficiently, that is, to reproduce as work a satisfactory percentage of the heat energy available in the steam, it is necessary to use steam of high pressure, and to use a high ratio of expansion. In order to avoid the condensation losses and the mechanical difficulties attendant on the use of a high ratio of expansion in a single cylinder, compound cylinders are



FIG. 2.—SINGLE-EXPANSION CONSOLIDATED TYPE LOCOMOTIVE. BUILT FOR THE NATIONAL R. R. CO. OF MEXICO BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA

Cylinders—Diameter.....	21 inches	Heating surface—Tubes.....	3002 square feet
Stroke.....	30 inches	Firebox.....	138 square feet
Driving wheel diameter.....	56 inches	Total.....	3140 square feet
Boiler pressure.....	200 pounds per square inch	Grate area.....	52.2 square feet
Weight in service—On driving wheels.....	164,300 pounds		
Total locomotive.....	188,000 pounds		
Locomotive with half loaded tender.....	315,000 pounds		

often used, that is, the steam is expanded successively in two cylinders.

The amount of steam required to develop a given amount of work will vary considerably with the conditions of service. With a single-expansion engine in slow-speed service, about 45 pounds of steam per hour may be required for each horse-power in the cylinders, while a high-speed compound locomotive can develop a horse-power on about 25 pounds of steam per hour.

The power which can be developed by the locomotive is determined by the rate at which the boiler produces steam, and by the rate at which the cylinders consume it. For example, suppose the boiler is capable of producing 40,000 pounds of steam per hour, then if the cylinders use 40 pounds per horse-power hour, the locomotive will be capable of delivering 1000 H. P. continuously, while if the cylinders are improved so that they can produce a horse-power with 32 pounds of steam per hour, the locomotive will be capable of developing 1250 H. P.

4.—IMPULSION BY THE ADHESION OF THE DRIVING WHEELS

The driving wheels are rotated by the cylinders, and by reason of the friction between the wheels and the rails, the locomotive is impelled forward. This adhesion of the driving wheels to the rails sets a limit to the tractive power of a locomotive, for if the cylinder power be increased beyond a certain point, the wheels will begin to slip and the tractive power will not be increased, but will be actually diminished as the wheels slip. The tractive power of a locomotive is thus limited, independently of the cylinder power, by the weight on the driving wheels, and by the friction between the drivers and the rails. If the rails are dry and well sanded, it is possible to utilize as tractive power as much as 30 per cent. of the weight on the driving wheels, but a more usual figure to represent fairly good everyday conditions is $23\frac{1}{2}$ per cent. of the weight on driving wheels available for tractive power.

This, taken in connection with the allowable load on each wheel deter-

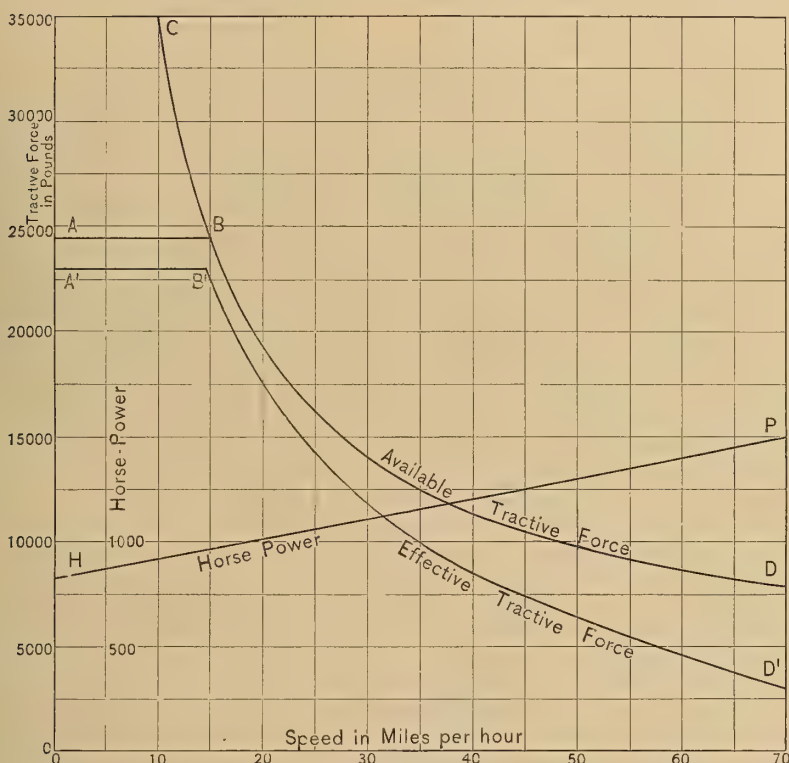


FIG. 3.—CHARACTERISTIC CURVES FOR ATLANTIC TYPE LOCOMOTIVE SHOWN IN FIG. 1

mines the number of driving wheels. For example, a locomotive is required to develop a tractive effort of 20,000 pounds on starting.* This engine must have at least four and a quarter times this amount, that is, 85,000 pounds on the driving wheels. Then, if the maximum allowable weight per axle is 32,000 pounds, the adhesive weight as found above must be distributed over three axles. The engine must have six driving wheels. Naturally, in the interests of simplicity, the number of driving wheels will be kept down to the minimum practicable.

The foregoing gives in broad outline the fundamental principles which govern the development of power in a locomotive. To produce satisfactory results, each of the four pro-

cesses described must be carried out properly, and the efficiency of the locomotive, as a whole, depends on the efficiency of each process, and the proper co-ordination of the four processes.

The power developed by a locomotive is measured by the product of two factors, the tractive force and the speed, the relation being,—

$$P = \frac{T \cdot V}{375} \quad (1)$$

where P is the horse-power.

T is the tractive fore in pounds.

V is the speed in miles per hour.

From this relation and the principles established, a characteristic curve can be drawn for any locomotive to show the limitations of its power in relation to the speed. Such curves drawn for the locomotives

* Of the power developed by the cylinders, part is consumed in overcoming the resistance of the locomotive and tender, while the remainder can be usefully employed in hauling the train.

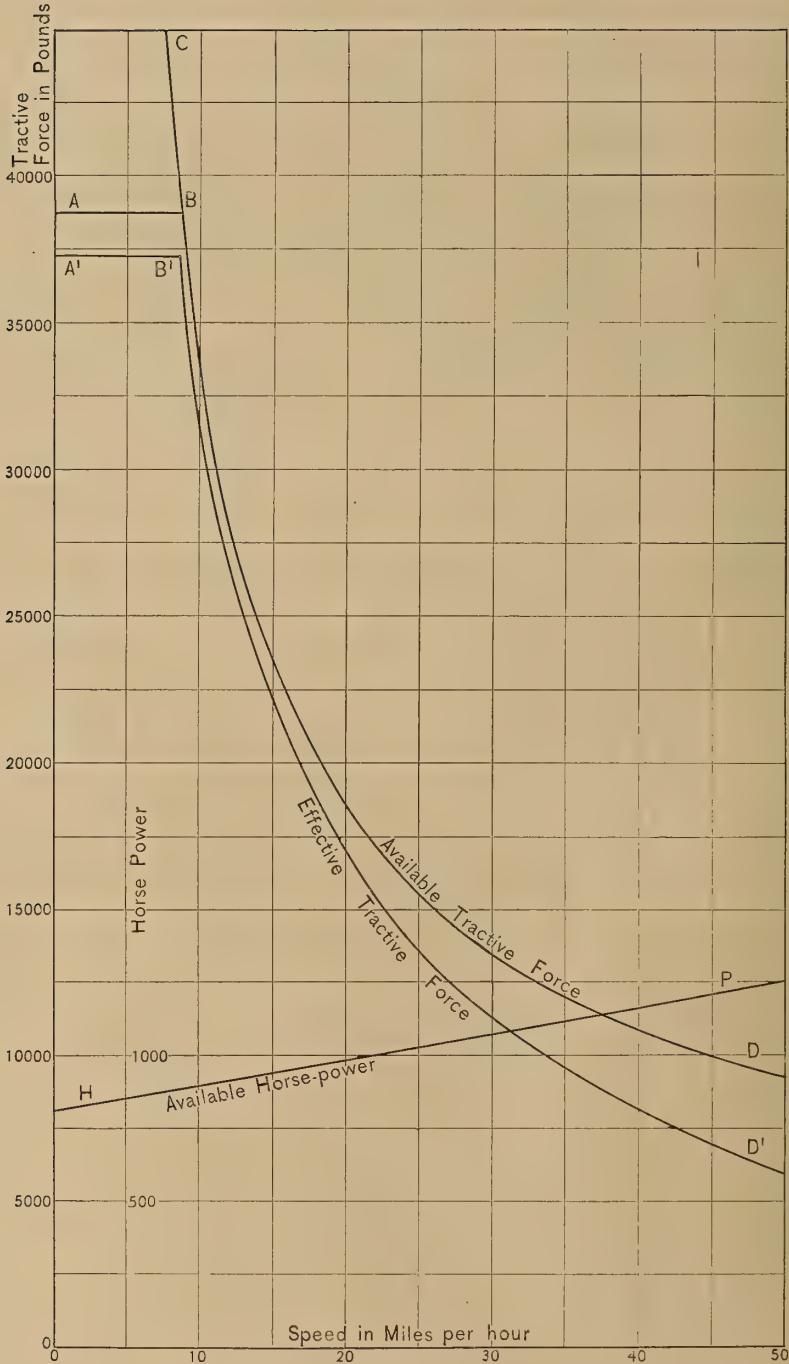


FIG. 4.—CHARACTERISTIC CURVES FOR CONSOLIDATION TYPE LOCOMOTIVE SHOWN IN FIG. 2

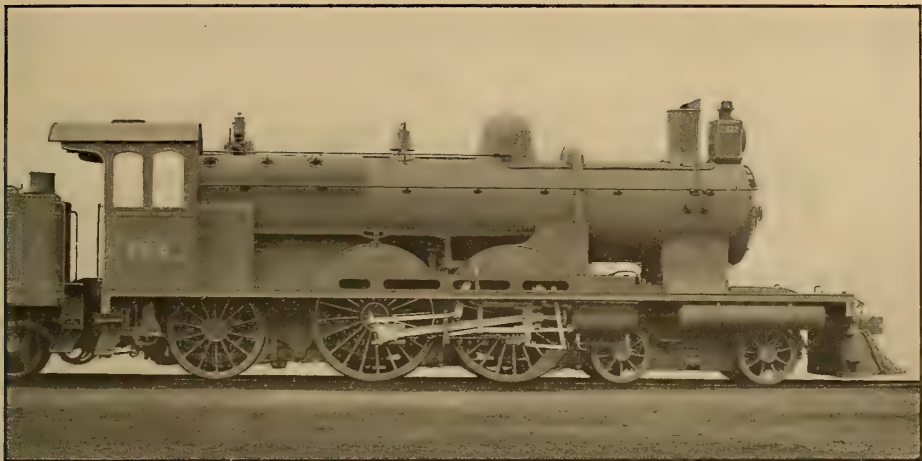


FIG. 5.—FOUR-CYLINDER COMPOUND ATLANTIC TYPE EXPRESS LOCOMOTIVE. BUILT FOR THE PENNSYLVANIA RAILROAD BY THE SOCIETE ALSACIENNE DE CONSTRUCTIONS MECANIQUES, BELFORT, FRANCE

Cylinders—High-pressure.....	14.2X25.2 inches	Heating surface—Tubes.....	2480 square feet
Low-pressure.....	23.6X25.2 inches	Firebox.....	177 square feet
Driving wheel diameter.....	80 inches	Total.....	2657 square feet
Boiler pressure.....	225 pounds per square inch	Grate area.....	33.4 square feet
Weight in service—On driving wheels.....			87,850 pounds
Total locomotive.....			164,000 pounds

shown in Fig. 1 and Fig. 2 are given in Figs. 3 and 4.

If the grate is of sufficient size, the maximum horse-power which the engine can develop will be determined, as previously explained, by the steam

production of the heating surface and the steam consumption of the cylinders. The efficiencies of both steam production and steam consumption are slightly increased with increasing speed. For the purposes of the pres-

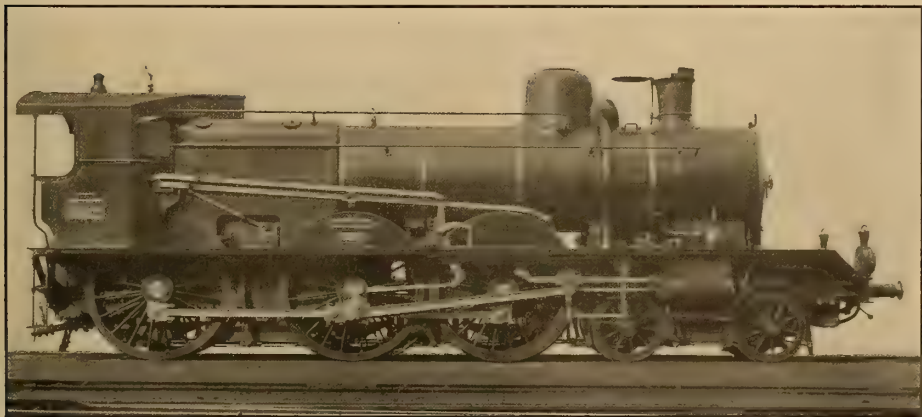


FIG. 6.—FOUR-CYLINDER COMPOUND TEN-WHEELED EXPRESS LOCOMOTIVE ON THE PARIS-LYONS-MEDITERRANEAN RAILWAY, FRANCE

Cylinders—High-pressure.....	13.4X25.6 inches	Heating surface—Tubes.....	2208 square feet
Low-pressure.....	21.3X25.6 inches	Firebox.....	166 square feet
Driving wheel diameter.....	78.8 inches	Total.....	2374 square feet
Boiler pressure.....	228 pounds per square inch	Grate area.....	32.3 square feet
Weight in service—On driving wheels.....			116,000 pounds
Total locomotive.....			155,800 pounds
Locomotive with half loaded tender.....			224,600 pounds

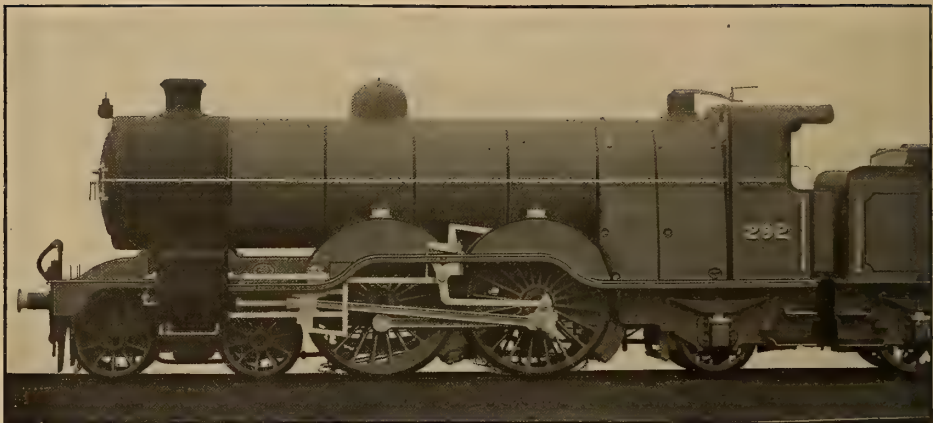


FIG. 7.—FOUR-CYLINDER COMPOUND ATLANTIC TYPE EXPRESS LOCOMOTIVE FOR THE GREAT NORTHERN RAILWAY FROM THE DONCASTER WORKS, ENGLAND

Cylinders—High-pressure.....	13x20 inches	Heating surface—Tubes.....	2350 square feet
Low-pressure.....	16x26 inches	Firebox.....	141 square feet
Driving wheel diameter.....	80 inches	Total.....	2500 square feet
Boiler pressure.....	200 pounds per square inch	Grate area.....	31 square feet
Weight in service—On driving wheels.....		Total locomotive.....	81,800 pounds
		Locomotive with half loaded tender.....	154,600 pounds
			243,600 pounds

ent illustration of general principles, it may be taken that at 50 miles an hour, each 2.5 square feet of the total heating surface produce 1 H. P. in the cylinders, while at 10 miles an hour, 3.5 square feet of total heating surface are required for each horse-power. By calculating the horse-power at these speeds for each of the locomotives in Figs. 1 and 2, and assuming that the change of horse-power with the speed follows a straight line, the lines *HP* in Figs. 3 and 4 are obtained. These lines show the horse-power available at any speed, and the tractive force available can be calculated from equation (1).

The figures from such a calculation are shown in Tables I. and II., and the results are plotted in the hyperbolic curves *CD*. These curves show how the limit placed on the available tractive effort varies with the speed. There is another limiting factor for the tractive effort as was seen in the consideration of the adhesion of the driving wheels. The tractive effort can never exceed the friction between the driving wheels and the rails, and this may, for working conditions, be taken at 23.5 per cent. of

the weight on the driving wheels. On this basis the Consolidation engine in Fig. 2 will have a maximum tractive force of 37,000 pounds, and

TABLE I.—HORSE-POWER, TRACTIVE FORCE, AND RESISTANCE, AT VARIOUS SPEEDS OF ATLANTIC TYPE LOCOMOTIVE. FIG. 1

Speed M. P. Hr.	Boiler Horse- power H. P.	Available Tractive Force Pounds	Resistance of Locomo- tive and Tender Pounds	Effective Tractive Force Pounds
10	928	34,800	1,430	32,370
15	975	24,400	1,570	22,830
20	1,021	19,150	1,730	17,420
30	1,114	13,900	2,150	11,750
40	1,207	11,300	2,670	8,630
50	1,300	9,750	3,310	6,440
60	1,393	8,530	4,070	4,460
70	1,486	7,980	4,910	3,070

TABLE II.—HORSE-POWER, TRACTIVE FORCE AND RESISTANCE, AT VARIOUS SPEEDS OF CONSOLIDATION TYPE LOCOMOTIVE. FIG. 2

Speed M. P. Hr.	Boiler Horse- power H. P.	Available Tractive Force Pounds	Resistance of Locomo- tive and Tender Pounds	Effective Tractive Force Pounds
10	900	33,800	1,450	33,350
15	944	23,600	1,600	22,000
20	988	18,530	1,760	16,770
30	1,076	13,450	2,180	11,270
40	1,164	10,900	2,720	8,180
50	1,252	9,310	3,360	5,950

the Atlantic type in Fig. 1, a maximum tractive effort of 23,000 pounds. The lines *AB* are drawn for these values. They are horizontal, since the adhesion effect is not affected by the speed. Then the maximum trac-

tive force available at all speeds is shown by the complete characteristic ABD . This tractive force is that which is available for the impulsion of the locomotive and the train.

To determine the effective tractive force which can be usefully employed in hauling the train, the force necessary to overcome the resistance of the locomotive and tender must be deducted from the total available tractive force. The resistance of the

D' is obtained. This curve determines the effective tractive force which can be usefully employed.

In drawing these characteristics, the size of the cylinders has not been taken into consideration. It is assumed that the cylinders are properly proportioned so that, on starting, they will fully utilize the weight on the driving wheels, by developing a tractive force at least equal to that rendered available by the adhesion of

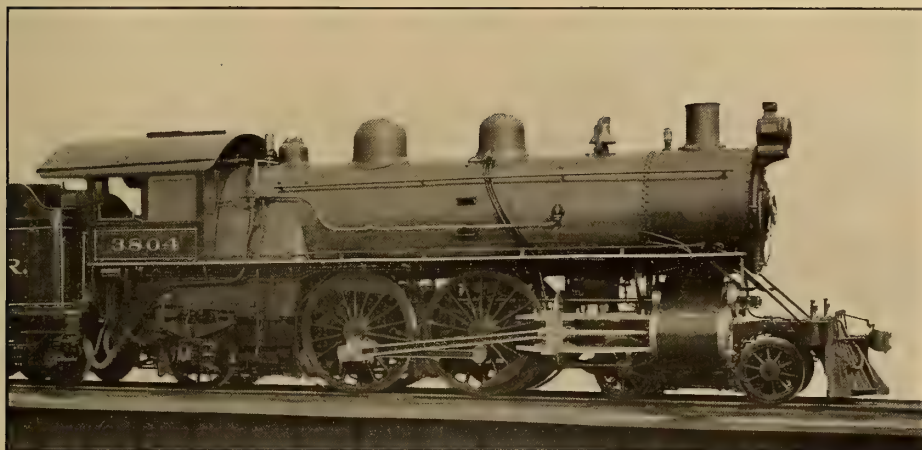


FIG. 8.—FOUR-CYLINDER COMPOUND ATLANTIC TYPE EXPRESS LOCOMOTIVE. BUILT FOR THE NEW YORK CENTRAL & HUDSON RIVER RAILROAD BY THE BALDWIN LOCOMOTIVE WORKS

Cylinders—High-pressure.....	152½x26 inches	Heating surface—Tubes.....	3450 square feet
Low-pressure.....	26x26 inches	Firebox*.....	160 square feet
Driving wheel diameter.....	79 inches	Total.....	3628 square feet
Boiler pressure.....	225 pounds per square inch	Grate area.....	50.3 square feet
Weight in service—On driving wheels.....			106,800 pounds
Total locomotive.....			204,500 pounds
Locomotive with half loaded tender.....			295,000 pounds

*Including 23 square feet in firebrick tubes.

locomotive and tender may be calculated from the following formula, which is slightly modified from that proposed by von Borries,—

$$R = 8 + 0.087V + 0.0036V^2 \quad (2)$$

where R is the resistance in pounds per ton (2000 pounds) of the engine and tender, and V is the speed in miles per hour.

The resistance for the locomotives under consideration, calculated for a half-loaded tender, is shown in the tables, and the force of this resistance, being deducted from the available tractive force, the curve $A' B'$

the wheels. Under these conditions the cylinders will not limit the power at any speed, but will be always capable of developing the full tractive force which the "characteristic" shows to be available.

A study of the characteristic curves is of assistance in an investigation of the development of the locomotive. In the cases of the two curves given in the figures, the general form is the same, but there are marked differences due to the different character of the service for which the two engines are destined. The Consolidation engine, being designed for

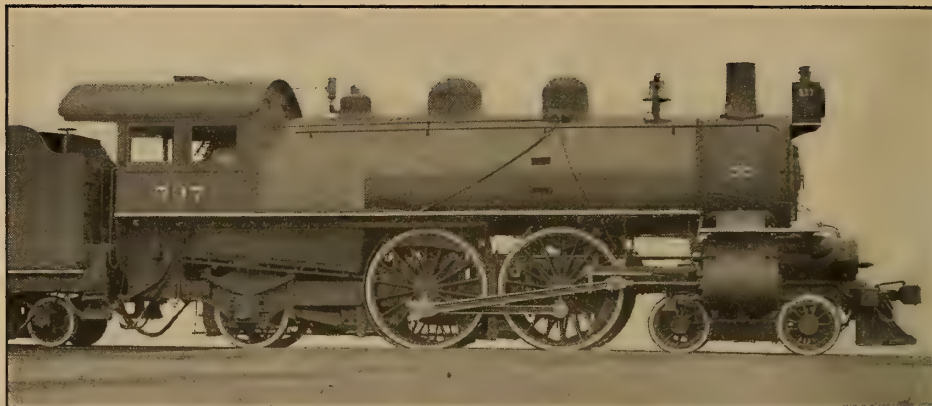


FIG. 9.—FOUR-CYLINDER COMPOUND ATLANTIC TYPE EXPRESS LOCOMOTIVE FOR THE ERIE RAILROAD COMPANY.
BUILT BY THE AMERICAN LOCOMOTIVE COMPANY, NEW YORK

Cylinders—High-pressure.....	15½x26 inches	Heating surface—Tubes.....	3434 square feet
Low-pressure.....	26x26 inches	Firebox.....	188 square feet
Driving wheel diameter.....	73 inches	Total.....	3622 square feet
Boiler pressure.....	220 pounds per square inch	Grate area.....	56.3 square feet
Weight in service—On driving wheels.....			115,000 pounds
Total locomotive.....			206,000 pounds
Locomotive with half loaded tender.....			333,000 pounds

heavy trains and slow speeds, has a maximum effective tractive force, or tender draw-bar pull, of 37,300 pounds, which is available up to a speed of only about $8\frac{1}{2}$ miles an hour, from which point the boiler capacity reduces the draw-bar pull as the

speed increases. The small diameter of the driving wheels limits the speed. The characteristic is carried out to 50 miles an hour, but an engine of this type will not do much work at any speed over about half of this figure.



FIG. 10.—FOUR-CYLINDER COMPOUND PACIFIC TYPE EXPRESS LOCOMOTIVE. BUILT FOR THE OREGON RAILROAD & NAVIGATION COMPANY BY THE BALDWIN LOCOMOTIVE WORKS

Cylinders—High-pressure.....	17x22 inches	Heating surface—Tubes.....	2874 square feet
Low-pressure.....	28x28 inches	Firebox.....	179 square feet
Diameter of driving wheels.....	77 inches	Total.....	3053 square feet
Boiler pressure.....	200 pounds per square inch	Grate area.....	49.5 square feet
Weight in service—On driving wheels.....			143,600 pounds
Total locomotive.....			231,300 pounds
Locomotive with half loaded tender.....			346,000 pounds

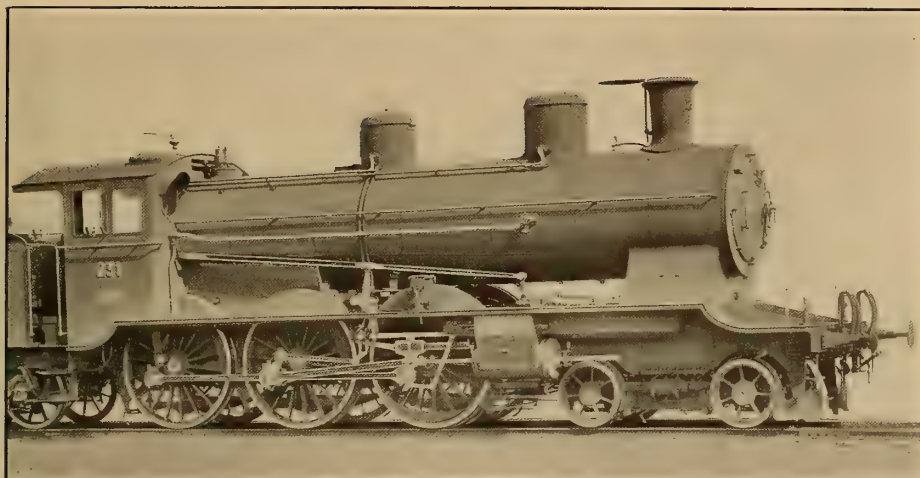


FIG. 11.—FOUR-CYLINDER COMPOUND TEN-WHEELED EXPRESS LOCOMOTIVE. BUILT BY THE SWISS LOCOMOTIVE AND MACHINE WORKS, WINTERTHUR, SWITZERLAND

Cylinders—High-pressure.....	14. 2x26 inches	Heating surface—Flues.....	1651 square feet
Low-pressure.....	22. 4x26 inches	Firebox.....	167 square feet
Driving wheel diameter.....	70 inches	Total.....	1818 square feet
Working boiler pressure, 213 pounds square inch		Grate area.....	16.2 square feet
Weight in service—On driving wheels.....	101,600 pounds		
Total locomotive.....	142,200 pounds		
Total locomotive with half loaded tender..	203,400 pounds		

The Atlantic type passenger locomotive at low speeds requires only sufficient tractive force to accelerate a comparatively light train, and the draw-bar pull does not rise above 23,000 pounds, which is available up to nearly 15 miles an hour.

With the same total weight of engine, an Atlantic type will have about 10 per cent. more heating surface than a Consolidation type locomotive. In the cases illustrated, the Atlantic type weighs 56.5 pounds for each square foot of heating surface, while the Consolidation weighs 60.5 pounds. These are favourable examples, and the average weight in American practice will be nearer 60 pounds for the Atlantic type, and 65 for the Consolidation. The difference in weight is due to the lighter weight of the driving wheels and connecting rods of the Atlantic type.

Now to apply the principles set forth to the problems of design and of the development of the future. The essential problem before the locomotive designers is to keep up a growth in the power of the locomo-

tives produced, and at the same time to avoid an excessive increase in the cost of maintenance and in the fuel consumption. In passenger service the constant tendency is to increase the comfort of the passengers and thus add to the weight of the trains while the speed is increased, rather than reduced. In freight service the demand is for powerful engines to take advantage of the economy obtainable by means of large train loads. Broadly speaking, each new design for a locomotive is required to give more power than the preceding. To maintain this growth is becoming increasingly difficult.

The characteristics already plotted show the principles which must be followed in securing an increase in power, while an examination of current types of locomotives will show the direction which the practical application of these principles is taking.

From the characteristics it is obvious that at slow speeds the tractive power depends solely on the weight of driving wheels. At higher speeds the matter is slightly more

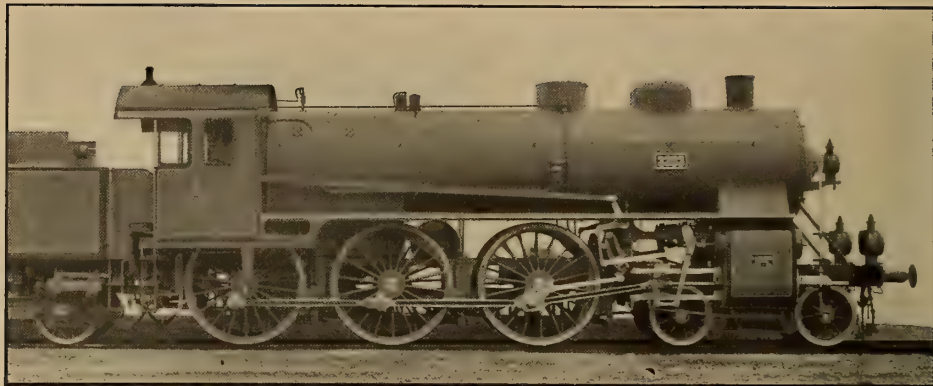


FIG. 12.—FOUR-CYLINDER COMPOUND TEN-WHEELED EXPRESS LOCOMOTIVE FOR THE BAVARIAN STATE RAILWAYS. BUILT BY J. A. MAFFEI, MUNICH, GERMANY

Cylinders—High-pressure.....	13. 4X25. 2 inches	Heating surface—Tubes.....	2250 square feet
Low-pressure.....	22. 4X25. 2 inches	Firebox.....	155 square feet
Driving wheel diameter.....	73. 6 inches	Total.....	2405 square feet
Boiler pressure.....	228 pounds per square inch	Grate area.....	35. 3 square feet
Weight in service—On driving wheels.....		Total locomotive.....	100,500 pounds
		Locomotive.....	151,200 pounds
		Locomotive with half loaded tender.....	230,600 pounds

complicated. The effective tractive force is increased by any measure which raises the line $B' D'$. This may be done by increasing the horsepower, thus increasing the available tractive effort. In the figure this has the effect of raising the line $B D$ and the distance between the two lines not being altered, the line $B' D'$ is also raised. Again, if without any change in the line $B D$, the distance between the two lines is lessened, that is to say, the resistance of the locomotive and tender is reduced, the line $B' D'$ will be raised and the effective tractive force increased.

The resistance of the locomotive at high speed is mainly due to the air resistance, and therefore the specific resistance, that is, the resistance per ton weight, can probably not be greatly reduced. Some reduction can be effected by giving the locomotive a suitable shape, and attempts in this direction are shown in Figs. 12 and 13 where the smoke-box front is made conical. At best, however, only a small part of the surface of the locomotive can be given a shape of small resistance, and the better plan appears to be to recognize that the specific resistance must remain high,

and to keep down the total resistance by making the locomotive and tender as light as possible. This method, in connection with the raising of the line $B' D'$, that is, the increasing of the total available tractive power by increasing the horse-power, is a combination of the best principles of locomotive development.

The horse-power is a function of the total heating surface, the rate of steam production and the efficiency of the utilization of the steam. The power of any locomotive may be surpassed in a new design by modifying any of these three coefficients. An increase in the heating surface entails an increase in the weight, and this increases the total resistance so that the whole gain in power is not effective in moving the train. A more efficient plan is to increase either the rate of steam production, or the efficiency of the utilization of the steam.

The rate of steam production is determined by the type of boiler employed. The present locomotive boiler may possibly be replaced eventually by a water-tube boiler with a higher rate of steam production, but the present type of boiler lends itself so

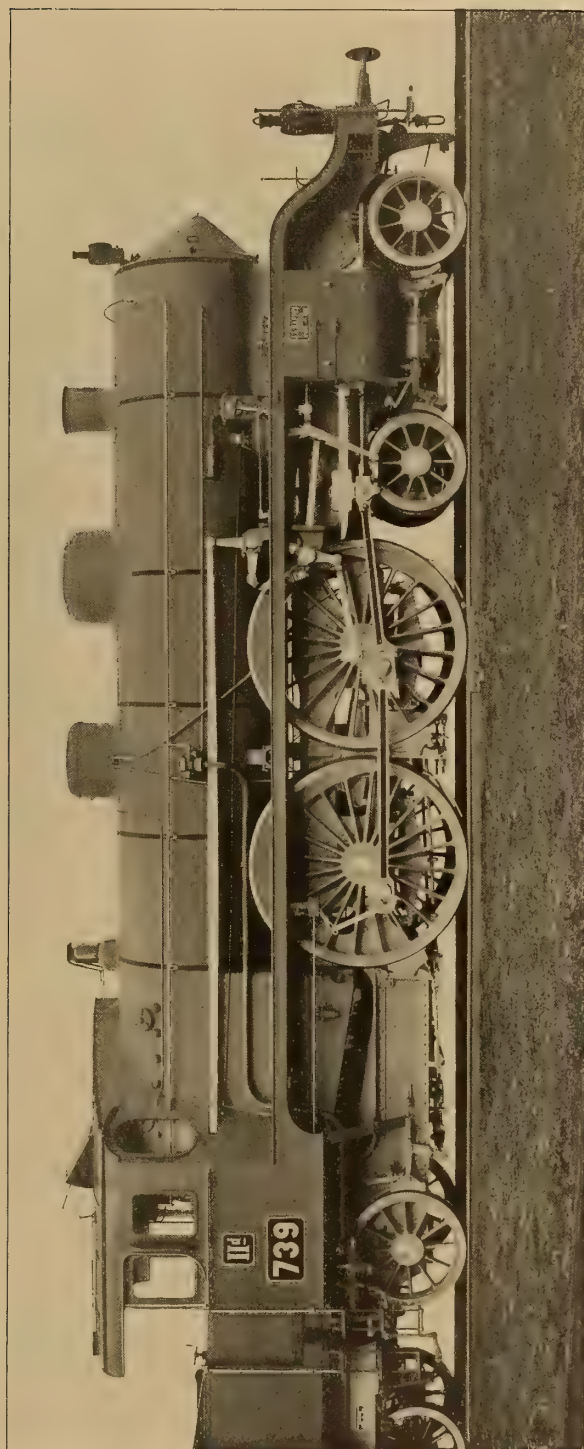


FIG. 13.—FOUR-CYLINDER COMPOUND ATLANTIC TYPE EXPRESS LOCOMOTIVE FOR THE BADEN STATE RAILWAYS. J. A. MAFFEL, MUNICH, GERMANY

Cylinders—High-pressure.....	13.2x24.4 inches	Heating surface—Tubes.....	2355 square feet
Low-pressure.....	22.4x24.4 inches	Firebox.....	146 square feet
Driving wheel diameter.....	87.7 inches	Total.....	2501 square feet
Boiler pressure.....	228 pounds per square inch	Grate area.....	29.0 square feet
Weight in service—			
On driving wheels.....			76,300 pounds
Total locomotives.....			103,400 pounds
Locomotive with half loaded tender.....			242,800 pounds

well to the constructional requirements of the locomotive, and gives such satisfactory evaporative results with such simplicity that there is no immediate prospect of a widespread change.

Of the three coefficients of efficiency, this leaves for consideration the utilization of the steam. The simplest form of locomotive, from which all development proceeds, is provided with two single-expansion cylinders, operated by a simple link motion. The simplicity of this form of engine has brought it into the widest favour, but, with the necessity for growth, many plants have been offered for increasing the efficiency. High steam pressures, special valve motions, compound cylinders, and superheated steam have been tried in different parts of the world with varying measures of success.

The most successful lines of development at the present time are shown by the locomotives in the accompanying illustrations. Ten examples of powerful high-speed locomotives are given and these are typical of the most advanced practice in Great Britain, France, Germany, Switzerland, and America.

France is represented by two locomotives, Figs. 5 and 6. The former is an Atlantic type engine with compound cylinders on the de Glehn system. It was built for the Pennsylvania Railroad to the same dimensions as used by the Paris-Orleans Railway. The two high-pressure cylinders are seen outside the frames, connected to the second pair of driving wheels. The two low-pressure cylinders are placed between the frames ahead of the outside cylinders and are connected to the front driving axle. The low-pressure cylinders have slide valves, and the high-pressure cylinders, piston valves. Each pair of valves is driven by an independent Walschaert valve motion, so that the admission in each pair of cylinders can be varied independently. This type of engine is due to M. de Glehn, of the Société Alsacienne de

Constructions Mécaniques and M. du Bousquet, of the Northern Railway of France, the first two engines having been built in 1884 for that railway. These two engines did not have coupling rods, but in the next engines, rods were added and advantage was thus taken of the four-cylinder balancing.

The engine shown in Fig. 6 is a ten-wheel express locomotive for the Paris-Lyons Mediterranean Railway with the Henry system of compound cylinders. The high-pressure cylinders are outside the frames and drive the second pair of wheels. The low-pressure cylinders, which drive the first axle, are inside the frames, but slightly ahead of the outside cylinders. There are two independent valve motions for each pair of cylinders, but the admission is variable only in the high-pressure cylinders. The low-pressure cut-off is permanently fixed at 63 per cent. of the stroke. The first engine of this type of compounding was built in 1889. The de Glehn and the Henry engines were the pioneers in France of the balanced compound locomotives, which have since appeared in such large numbers. Mr. Sauvage reports that on January 1, 1900, there were in service or on order in France, 803 balanced compound locomotives, while by October 1, 1903, this number had increased to 1571.

Fig. 7 shows an English balanced compound designed by H. A. Ivatt, of the Great Northern Railway, and built at the company's works at Doncaster. The high-pressure cylinders are outside the frames and drive the second axle while the low-pressure cylinders lie between the frames and are connected to the front driving axle. Each pair of cylinders has its independent valve motion.

Fig. 8 shows the most widely spread type of American balanced compound. This engine was built by the Baldwin Locomotive Works for the New York Central & Hudson River Railroad. The four cylinders all lie in the same transverse line

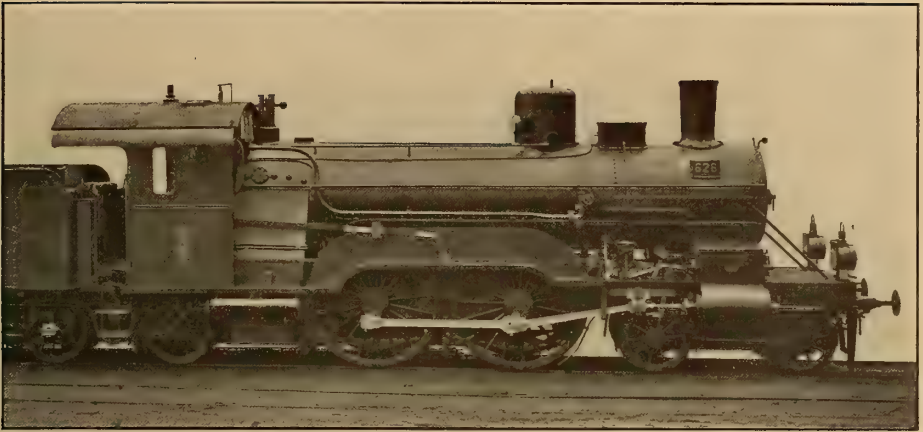


FIG. 14.—FOUR-CYLINDER COMPOUND ATLANTIC TYPE EXPRESS LOCOMOTIVE WITH PIELOCK SUPERHEATER FOR THE RUSSIAN STATE RAILWAYS. BUILT BY THE HANOVER MACHINE WORKS COMPANY, HANOVER, GERMANY

Cylinders—High-pressure.....	14.2X23.6 inches	Heating surface—Flues.....	1830 square feet
Low-pressure.....	22.0X23.6 inches	Firebox.....	108 square feet
Driving wheel diameter.....	78 inches	Total.....	1938 square feet
Boiler pressure.....	199 pounds per square inch	Grate area.....	29.0 square feet
Weight in service—On driving wheels.....	67,000 pounds		
Total locomotive.....	132,700 pounds		
Total locomotive with half loaded tender..	203,000 pounds		

across the engine, with the high-pressure cylinders between the frames and the low-pressure cylinders outside. The inside cylinders are connected to the front, and the outside cylinders to the second driving axle. There are only two piston valves for the four cylinders, so that only one set of valves is required. The wide American load gauge enables the low-pressure cylinders to be placed outside the frames and to be made of sufficient diameter to have a volume nearly three times that of the high-pressure cylinders. This large ratio enables satisfactory results to be obtained, with a single valve motion, and consequently no variation of the relation of the high-pressure cut-off to the low-pressure cut-off.

This elimination of the second valve motion is a simplification which is of considerable value from the point of view of American practice. This system of compounding was designed by S. M. Vauclain, of the Baldwin works. The first engine was built in 1902 and was the first balanced compound to give commercially successful results in America.

Fig. 9 shows a balanced compound

built by the American Locomotive Company in accordance with the patterns of F. J. Cole, for the Erie Railroad. The low-pressure cylinders are outside the frames, and the high-pressure cylinders are inside and ahead of the outside cylinders. The back heads of the high-pressure cylinders are in the same plane across the engine as the front heads of the low-pressure cylinders. A single valve chest and a combination valve serve each high-pressure and its corresponding low-pressure cylinder, so that only a single set of valve motion is required.

Fig 10 is a Vauclain balanced compound Pacific type locomotive, built by the Baldwin Locomotive Works for the Oregon Railroad & Navigation Company. The arrangement of the cylinders is the same as described above for Fig. 8, but in this case all four cylinders are connected to the second driving axle, the inside main rods being forked so as to pass the front axle.

Fig. 11 is an example of Swiss practice, being a ten-wheeled locomotive, built by the Swiss Locomotive & Machine Works, of Winter-

thur. The cylinders are placed as on the de Glehn compounds, the inside cylinders being ahead of the outside. There are two sets of valve motion, but both reverse shafts are connected to the same reverse lever.

The next three locomotives are samples of German practice, with the von Borries cylinder arrangement. Fig. 12 shows a ten-wheeled locomotive built by J. A. Maffei for the Bavarian State Railway. This engine was designed to haul trains of 300

engineer of this railway. With four carriages behind the tender, weighing 138 metric tons, this engine ran from Offenburg to Freiburg, a distance of 39 miles in 32.5 minutes, making an average speed of 72 miles an hour. The maximum speed was approximately at the rate of 87 miles an hour. Of the distance, the first 27 miles are practically level, and the remaining 12 miles have an average rise of 1 in 240.

Fig. 14 shows a von Borries com-

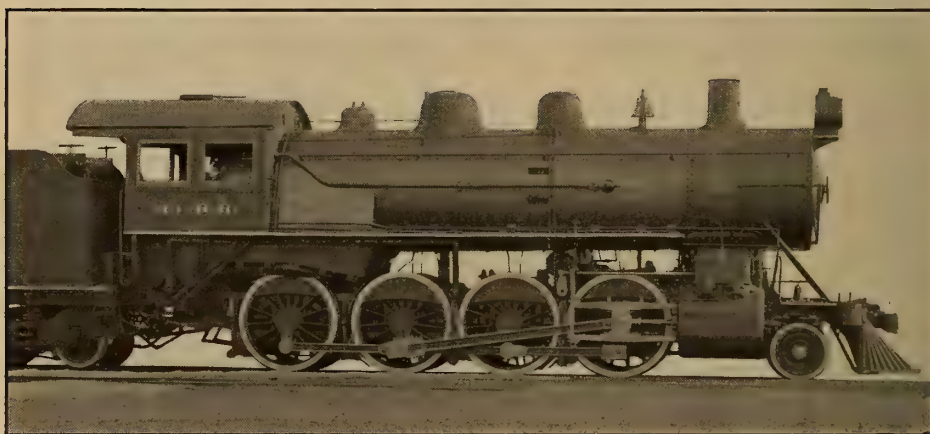


FIG. 15.—TWO-CYLINDER COMPOUND CONSOLIDATION FREIGHT LOCOMOTIVE. BUILT FOR THE MICHIGAN CENTRAL RAILROAD BY THE AMERICAN LOCOMOTIVE COMPANY

Cylinders—High-pressure.....	23x32 inches	Heating surface—Tubes.....	2912 square feet
Low-pressure.....	35x32 inches	Firebox.....	156 square feet
Driving wheel diameter.....	63 inches	Total.....	3091 square feet
Boiler pressure.....	210 pounds per square inch	Grate area.....	50.2 square feet
Weight in service—On driving wheels.....			174,000 pounds
Total locomotive.....			198,500 pounds
Locomotive with half loaded tender.....			292,000 pounds

metric tons behind the tender at 37 miles an hour on a grade of 1 in 100, and at 62 miles an hour on the level. The cylinders are all in the same line across the engine, the high-pressure being inside, and the low-pressure outside the frames. There is only one set of valve motion, but there are four valves, one for each cylinder. This arrangement of cylinders was first used by Von Borries on a locomotive built for the Prussian State Railways in 1897.

Fig. 13 shows an Atlantic type locomotive, built by J. A. Maffei for the Baden State Railway, under the supervision of Mr. Courtin, the chief

pound locomotive with Pielock superheater, built for the Prussian State Railway, and exhibited by the Hanover Machine Works Company at the St. Louis exhibition.

The foregoing illustrations, with one exception, are not isolated examples of the designs they typify, but each represents a considerable number of locomotives of the same class. The single exception is the engine for the Great Northern Railway of England. This engine, though not a representative of a large class, is of importance because it shows that Great Britain is not uninfluenced by the influences which are so important in

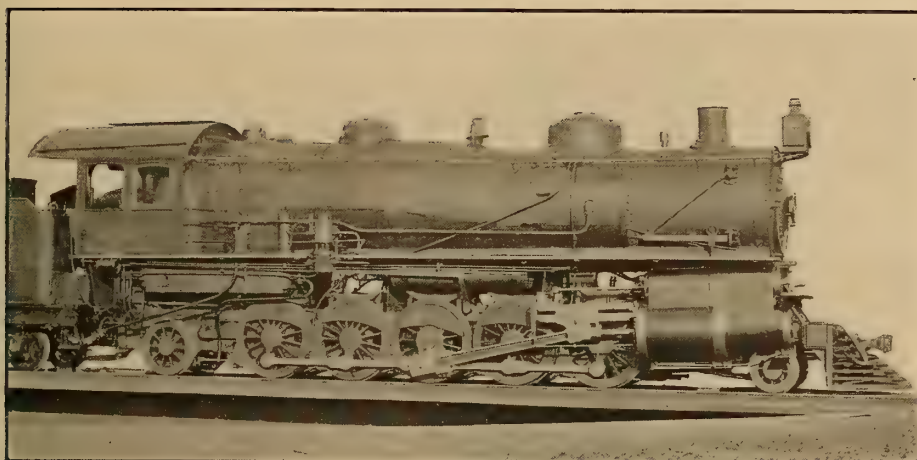


FIG. 16.—FOUR-CYLINDER TANDEM COMPOUND FREIGHT LOCOMOTIVE FOR THE ATCHISON, TOPEKA & SANTA FE RAILWAY. BUILT BY THE BALDWIN LOCOMOTIVE WORKS

Cylinders—High-pressure.....	19x32 inches	Heating surface—Tubes.....	4586 square feet
Low-pressure.....	32x32 inches	Firebox.....	210 square feet
Driving wheel diameter.....	57 inches	Total.....	4796 square feet
Boiler pressure.....	225 pounds per square inch	Grate area.....	58.5 square feet
Weight in service—On driving wheels.....			234,600 pounds
Total locomotive.....			287,200 pounds
Locomotive with half loaded tender.....			400,000 pounds

railways of other parts of the world.

Taken together, the illustrations show that in locomotive designing at the present day there is a marked convergence in the lines of development, and a growing recognition of the fact, almost obvious to the layman even, that the fundamental principles of correct design must be the same for all countries. Proper variations are, of course, necessary to meet local conditions, but the elementary principles must be the same.

All of the locomotives described above use high-pressure steam, and are of the four-cylinder, balanced-compound class. This is for many reasons the most approved class of locomotive for high-speed service.

In endeavouring to secure efficiency in the utilization of the steam, thermodynamic reasons make it imperative to use high-pressure steam and a long expansion. The high ratio of expansion required cannot,—speaking for the present purely from the point of view of steam economy,—be so efficiently carried out in a single cylinder as in two or more cylinders. If expanded in one stage

only, the condensation and piston leakage losses are too great for efficiency. In marine engines, where efficiency is of the first importance, single-expansion engines in the large sizes have been altogether superseded by multiple-expansion engines. In locomotive practice steam economy is of great importance, but the difficulties of maintenance make unnecessary complication undesirable, and thus practically limit the number of successive expansions to two.

By using four cylinders, two high and low pressure, and placing them so that each high-pressure piston moves in the opposite direction to the corresponding low-pressure piston, both the internal and external forces can be largely balanced. Where only two cylinders are used, the moving parts of the engine must perforce be largely left unbalanced and at high speeds, the engine racks itself to pieces, and exerts a destructive influence on the track. With the perfect balance obtainable with four cylinders these difficulties may be largely avoided. The mechanical advantages of proper balancing are ob-

tainable with four high-pressure cylinders, but the four-cylinder compound adds to the balancing the economies resulting from the double expansion of the steam. To this combination of advantages is due the high place taken in modern locomotive practice by engines of the four-cylinder balanced compound class.

Some of the locomotives illustrated are six-coupled and some four-coupled. This difference is not fundamental. It is merely, as has been already noted, a question of the tractive force required and the allowable weight on a pair of driving wheels. In Europe the allowable weight on each axle does not exceed from 15 to 18 tons, while in America the roads are built to carry up to 25 tons on one axle. The effect is shown in the illustrations. To obtain 100,500 pounds on the driving wheels, the Bavarian State engine shown in Fig. 12 is given three-coupled driving axles, while the New York Central and the Erie Railroads both use considerably greater adhesive weights, carried on only two driving axles.

The power of a locomotive at slow speed was shown by the characteristic curve in Fig. 4 to be determined by the weight on driving wheels. Any desired power can be secured by increasing the number of driven axles, the weight on each axle being made as great as the condition of the roadbed will permit. An increase in the number of coupled axles increases the number of wearing parts and the internal friction of the locomotive, and is consequently undesirable. The objections on this score increase rapidly with the speed. In slow-speed service locomotives with five and six-driven axles are in satisfactory service, while for high-speed service three coupled axles are practically the maximum, and it is desirable to have not more than two.

The illustrations show three heavy American locomotives for slow-speed freight service. Fig. 15 is a two-

cylinder compound freight locomotive, built by the American Locomotive Company. These locomotives are not so typical of general practice for slow-speed service as the other illustrations were of high-speed practice. There is less unanimity in the choice of designs where power is the desideratum than there is when speed is aimed at. The illustrations show, however, the direction in which development will probably take place.

At slow speed the balancing which required four cylinders driving cranks 90 degrees apart is not so necessary as at high speed, and, hence, other systems of compounding besides that with four balanced cylinders, are able to claim consideration. The locomotive shown in Fig. 15 is, as just stated, of the two-cylinder type, while that in Fig. 16 is a four-cylinder tandem type. A proposed Mallet compound has two high-pressure cylinders driving one group of six wheels, and the low-pressure cylinders driving another group of six wheels.

The two-cylinder compound can show practically the same efficiency of steam consumption as the four-cylinder, and has fewer working parts. On the other hand, the power developed is not always equally divided between the two sides of the engine and the excessive diameter of low-pressure cylinder, and consequently excessive width of locomotive required for high powers put a limit to the growth of this class of engine.

The tandem-compound gives equal power on both sides of the engine and economical steam consumption. The heavy reciprocating parts, due to both pistons being on the same rod make the engine difficult to balance, but at slow speeds this is not a great disadvantage. The example shown in Fig. 16 represents probably the maximum of power obtainable with this system of compounding. With five pairs of driving wheels the adhesive weight is 234,000 pounds, which is an average of 46,920, say



FIG. 17.—FOUR-CYLINDER MALLET COMPOUND ARTICULATED FREIGHT LOCOMOTIVE FOR THE GREAT NORTHERN RAILROAD (AMERICA), BALDWIN LOCOMOTIVE WORKS

Cylinders—High-pressure.....	23x32 inches	Heating surface—Tubes.....	5470 square feet
Low-pressure.....	35x32 inches	Firebox.....	230 square feet
Driving wheel diameter.....	53 inches	Total.....	5700 square feet
Boiler pressure.....	22½ pounds per square inch	Grate area.....	78 square feet
Weight in service—On driving wheels.....			
			316,000 pounds
Total locomotive.....			353,000 pounds

21 tons on each axle. This weight per axle is not susceptible of any considerable increase so that to give an engine of greater hauling capacity, it would be necessary to add another coupled axle. This would increase the rigid wheel base from 19 feet 9 inches to at least 24 feet 7 inches. Apart from the great internal resistance of a twelve-coupled engine of this description, the excessively long wheel base would render it extremely awkward for curves.

If more tractive force is required, the Mallet type compound already mentioned, seems to offer the greatest facilities for development. The twelve wheels are in two groups of six each, and as these groups have a flexible connection between them, the locomotive can curve easily. The rear group of wheels is driven by the two high-pressure cylinders and the front group by the two low-pressure cylinders, so that the same power is developed on both sides of the engine. The double expansion of the steam gives economy in fuel, and the whole construction of the locomotive is comparatively simple.

In locomotives of moderate power the simplicity of two cylinders may be of sufficient value to determine the choice in favour of the two-cylinder compound, or even the single-expansion type, but when great hauling capacity is required, the advantage of dividing the power to be developed between four instead of only two cylinders far outweighs the possible disadvantage of the multiplication of parts.

It is difficult to make an analysis of the use of special forms of valve motion, and of superheated steam, which shall determine the exact value of these phases of development. They have not yet secured a sufficiently

wide approval to remove an appraisal of them entirely beyond the field of speculation.

With a continued increase in the power of locomotives there must be an increase in the differences between those for high-speed and those for slow-speed service. For high-speed service four cylinders are desirable to give a satisfactory balance of the moving parts, and with four cylinders, economy is obtained by admitting steam to two of the cylinders and expanding it in the other two.

The high-speed locomotive of the future will surely be a four-cylinder balanced compound, using steam of high pressure. Where fuel is extremely expensive, it may be found advantageous to use superheated steam and an improved type of valve motion, but the margin which the compound leaves for economy by these means is so small that it appears to be quite an open question whether the gain in economy offsets the increased first cost and the larger cost of maintenance.

For low-speed service there are several possible lines of development. The tandem-compound with a rigid driving wheel base is capable of satisfactory service up to considerable power. Where the power required is not excessive, excellent results can be obtained with a single-expansion engine working with superheated steam. This is particularly advantageous in cases where bad water has to be used in the boiler, as the superheating enables a low boiler pressure to be used economically.

Where exceptionally great hauling power is required, the Mallet type of compound is undoubtedly the engine of the future. The remarks previously made regarding superheating and special valve motions apply with equal force here.

THE STABILITY OF SUBMARINES

By W. H. Stuart Garnett

ON the 3d of May, 1906, Sir William White read a paper on the stability of submarines before the Royal Society, in which he gave some exceedingly interesting figures as to the stability and dimensions of certain submarines in the Royal Navy, and particularly of the ill-fated "A8," whose sudden sinking in Plymouth Sound has been almost completely forgotten, but never in the least explained. Sir William White, in that paper, states the whole theory of the subject with his customary clearness and completeness. Be it immediately acknowledged that to the work of so eminent an authority we have nothing to add in connection with the subjects there discussed; but there are one or two points not raised in that paper which may yet deserve some consideration for the purpose of diminishing, as far as possible, the danger inseparable from submarine operations.

The discussion in the paper referred to is explicitly confined to the causes affecting the stability of a submarine boat when stationary, that is, to the statics of the subject. Mr. J. H. Jeans, of Trinity College, Cambridge, indicates in a letter to "Nature" how an approximation to the effect of the streams on a moving hull may be obtained by the aid of higher mathematics; but there are some further elements of the greatest importance, and capable of very simple investigation, which yet do not seem to have been taken into account in any published discussion of the subject.

It is perfectly clear that a vessel of the "Admiralty" type may sink unexpectedly through one of two

causes,—by filling through a leak or otherwise, and so increasing the weight of the hull, or by depressing her bow as the consequence of a longitudinal oscillation, and so plunging. The first is a statical cause, which may act whether the boat is at rest or in motion; the second can only affect a vessel under way. There is no question but that the Plymouth disaster and the recent sinking of the "Lutin" were both due to the second cause; the object of this paper is to discuss how the longitudinal oscillations resulting in the plunges in question were brought about.

It is common to divide the vessels now used for operations under water into two classes, the submersible and the submarine. The distinction between the two is in some sense the same as that between the balloon and the aeroplane, for the one is raised or lowered in the water by the filling and the emptying of tanks, the other is brought to a specific gravity slightly lower than that of water and is then raised or lowered by means of a horizontal rudder. Naturally, the submarine can be operated only when under way; in fact, we may say that the submersible sinks, but the submarine dives.

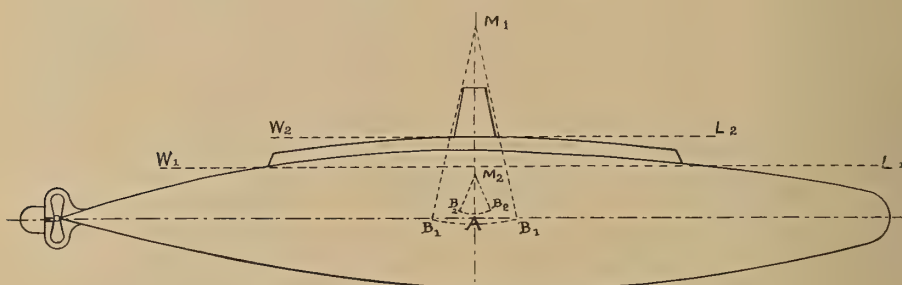
Of these two types the submarine is the only one used by the British Admiralty. The most modern specimens are vessels of a perfectly circular cross-section about 12 feet in diameter, broken only by a slightly raised backbone forming a hollow air chamber for a short part of its length, and expanding amidships into a small platform in which the hatch is situated and from which the conning tower rises to a height of some 6

feet. The length of the vessel is about 150 feet. The displacement, when submerged, cannot be far from 200 tons.

On the other hand, the actual weight of the ship and crew in cruising trim is considerably less. According to the figures used in illustration by Sir William White, the reserve of buoyancy at lightest draught would be about 13 tons in a vessel of this type, corresponding to an emersion of the hull of rather more than 18 inches in addition to

siderable load forward would be needed on this, as on any other ship, to depress the bow to an appreciable extent.

As we might expect, no case is on record of the loss of a submarine while manœuvring at the lightest draught. In both the great French disasters the ships were lost while actually engaged in diving. One of the fatal accidents which mark the history of British submarines,—the loss of "A1" off the Nab,—was due to a purely external and accidental



SUBMARINE OF 200 TONS DISPLACEMENT, 150 FT. LONG, 12 FT. BEAM

W_1L_1 , Water line at lightest draught; M_1 , Metacentre at lightest draught; B_1B_2 , Locus of centre of buoyancy at lightest draught; W_2L_2 , Water line when trimmed for diving; M_2 , Metacentre when trimmed for diving; B_2B_3 , Locus of centre of buoyancy when trimmed for diving. A , Centre of gravity. Vertical dimensions doubled.

the conning tower. Under these circumstances the water section would be nearly elliptical, about 90 feet long and 8 feet wide at the greatest beam. It will be found that the form of this section differs only slightly from the water section of a torpedo-boat reduced to half scale. As will be expected, the stability of a submarine under these circumstances is not very different from that of a normal vessel. The metacentres, both for rolling and pitching, can be constructed in the ordinary way, and while the metacentre for rolling will be found to be only slightly above the geometrical centre of the hull, that for pitching will be very much higher, and it is stated by Sir William White that it may in some cases be 37 feet above the centre of gravity. It follows that a submarine at the lightest draught may be very easily given a list to either side, but a very con-

cause; the other happened to submarine "A8" at Plymouth when she was traveling at full speed ahead with the water tanks rather more than half full. The fact is, that as the water tanks are filled, not only the buoyancy, but the stability, are rapidly diminished, until, when the boat is actually submerged, the conditions are entirely different from those prevailing in vessels of any other type known to naval architecture.

When the vessel is entirely submerged, the centre of gravity of the water displaced (that is, the centre of buoyancy) is at the geometrical centre of the vessel, a point which is a little above the axis of the hull, owing to the conning tower. Whatever position the boat may take up, whether plunging or rising, listing to port or to starboard, the centre of buoyancy never moves from that

point in the hull, and the supporting force always acts upwards through that point. The metacentre is, therefore, the centre of buoyancy, and it is the same for pitching as for rolling. While the transverse (or rolling) metacentre has come down, perhaps, 1 foot through the filling of the water tanks, the longitudinal (or pitching) metacentre has descended 37 feet. The stability of the ship is then entirely due to the fact that the centre of gravity is maintained, by keeping all heavy machinery low, at a certain depth below the geometrical centre of the boat. The weight acts downwards through the centre of gravity, the force of flotation upwards through the geometrical centre of a certain height above the centre of gravity. This height, according to the figures of Sir William White, is never greater than 9 inches.

Mechanically, then, the submerged submarine is a pendulum of 200 tons weight, suspended at a point,—in the most stable case,—9 inches above the centre of gravity. The metacentric height is small, but since under water the only cause that can operate to roll the vessel is the insignificant one of a man's weight moving from side to side of the ship, this does not greatly matter, so far as rolling is concerned. But turn to pitching; what is the effect of a man at the extreme bow (a distance of 75 feet from the metacentre) operating the torpedo? The weight of the vessel is 200 tons; that of the man we will assume to be 140 pounds,—1-15 of a ton. It is a question of balance about the metacentre, and with the man forward it will be found that the ship trims at an angle of 2 degrees by the head. But suppose the man to move forward from amidships to the extreme bow. The ship begins slowly to pitch, and swings from a position of 2 degrees above that in which she trims to a position 2 degrees below. The pitching does not actually cease until she is 4 degrees by the head. But we have the authority of Sir William White for

saying that "a very small amount of trim by the bow, in association with moderate speed when submerged, will bring a submarine to a considerable depth below the surface in a very short time." And what is true of the boat when submerged is almost equally true when "trimmed for diving."

The cases are not quite on all fours, however. The boat has a reserve of buoyancy alike when submerged and when on the surface, but when under water this reserve is counteracted by trimming by the head, and so bringing into play dynamical forces tending to keep her under. When on the surface, on the other hand, she is commonly trimmed by the stern, so as to get a certain support from the water through which she is being driven. But this very water which helps to support her tends also to make her trim unstable, and if by any accidental cause the axis of the ship is swung past the horizontal, these unstable wave forces forward will prevent her recovery, and tend to increase the angle at which she plunges. The ultimate reason for this is to be found in the law, well known alike in theory and practice, that a long, narrow body forced through a liquid tends to set itself across the direction of motion, a tendency exaggerated in this case by the peculiarities of surface waves and the turtle deck of the submarine.

There is, however, in submarine boats of the modern British type, a supremely important factor making for longitudinal stability, and that is the conning tower. When the vessel is trimmed for diving, the hull is entirely submerged with the exception of the conning tower, and, if the horizontal rudder is strongly applied, a portion of the deck forward. Under these circumstances the thrust of the screw is, as always, along the axis of the vessel, and the resistance of the water is substantially in the opposite direction along the same axis. When, however, the vessel be-

gins to plunge, the conning tower enters the water, and a new and substantial resistance comes into play. No doubt this has a certain effect in stopping the vessel, and the conning tower has been demurred to on this ground, but the important feature of the new resistance, from our point of view, is that its line of action is above that of the screw propeller, so that a couple is formed which slowly turns the bow up again, and in time must bring the vessel to the surface.

The course which would naturally be taken by a rudderless submarine would, therefore, consist of a series of short dives. After each dive the conning tower would bring the bow to the surface, and in all probability so far above the surface that the ves-

it is horrible to think of. It is not surprising that the standing order should run:—"Every member of the crew to remain in his station when trimmed for diving."

Has the order been obeyed? Sir William White does not believe that motion of the seamen could have accounted for the sudden disappearance of submarine "A8." He states that, at the court martial, "experienced witnesses asserted that they were not of opinion that the vessel could have been made to dive so suddenly if she possessed as much as six tons reserve of buoyancy." But he does not suggest any cause which might have led to that ill-fated plunge, and, in fact, it does not appear that any such cause has ever yet been suggested. It is admitted on all hands that the

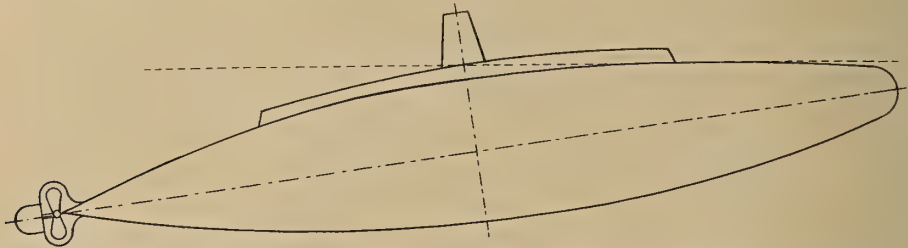


FIG. 2.—SUBMARINE WITH RESERVE BUOYANCY OF 3 TONS, TRIMMED FOUR DEGREES BY THE STERN, IN STILL WATER
Vertical dimensions doubled

sel would pitch with its weight and promptly dive again. This is precisely the course which is always taken by a clockwork model with a conning tower, and a most fascinating course it is to watch.

The conning tower will, as we have said, always bring the vessel ultimately to the surface, but a submarine 150 feet long may go both far and deep before reappearing. In nine cases out of ten no harm may be done; but if, as in the case of "A8," the hatch was open when she dived, or if, as was supposed to be the case with the "Lutin," the hull was in some way injured, to as to be unable to withstand the pressure at the depth which she attained, the result is one of those tragedies which

stability was small, and that the actual reserve of buoyancy at the time of the accident may have been rather less than was supposed, as the fact that the boat was trimmed four degrees by the stern would tend not only to raise the bow, but to lift the whole vessel rather above the static waterline; but in spite of these circumstances, it is contended that no known cause could have led to a pitching so violent as to have sunk the vessel in comparatively smooth water.

We must admit that we are unable to suggest a cause which would have proved adequate in water absolutely smooth, but in water where there is something of a ripple, still more, if there is the faintest suggestion of a

long ground swell, the case is entirely different, and it is at this point of our investigation that the circumstance that the boat was trimmed by the stern becomes highly material. Where a submarine is cruising on an even keel, the only difference between her pitching and that of a vessel of the common form is that the pitching of the submarine is,—thanks to her short water section,—slower. Where, however, the boat is trimmed by the stern, the conditions are very different. The stern itself is deeply submerged, and will not be exposed to the hollow of any sea of moderate size. On the other hand, the submersion of the bow is slight; in the case of a 150-foot boat trimmed 4 degrees by the stern, the bow is

the difference lies in the fact that there is no static waterline on the bow of the submarine. If the "supermarine" ship begins to pitch downwards in the bow, then so soon as the waterline is passed a powerful force of buoyancy is brought into play which very quickly stops the pitching, but in the case of the submarine the position of equilibrium is not reached until the bow is entirely submerged and no more buoyancy forward is brought into action by the mere fact that the depth of the already submerged bow beneath the surface is increased. In fact, no force of any adequacy to stop the pitching is brought into play until the stern rises above the water, and the probability is that this will never

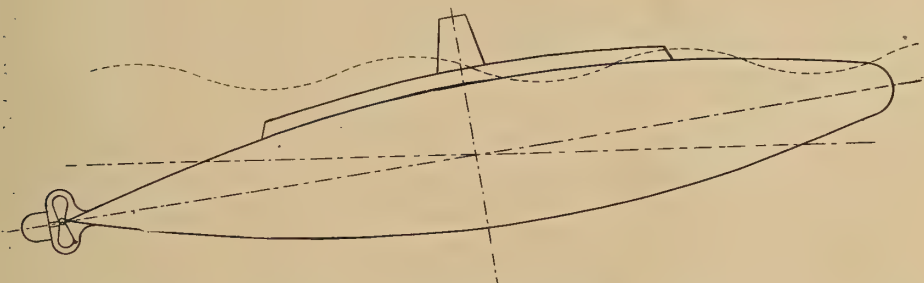


FIG. 3.—SUBMARINE WITH BUOYANCY OF 3 TONS, TRIMMED FOUR DEGREES BY THE STERN, IN SLIGHT ROLLERS
Vertical dimensions doubled

raised 4 feet above its normal position, and the top of the hull, right forward, is in the surface of the water, so as to be exposed by the slightest disturbance.

What happens, if the bow is suddenly exposed, is exactly what happens in the case of a rising boat breaking water suddenly bow foremost. She has a strong tendency to plunge again, performing a kind of porpoise evolution aptly illustrated by a clockwork model. It is a natural comment that the pitching of a steamer, which originates in this same fashion through the emersion of the bow, is promptly checked when the bow is immersed again to the waterline, and that the same should hold good of the submarine. But

happen, for in any case the stern cannot emerge until the axis is four or five degrees past the horizontal, and by that time, if the speed of the boat is considerable, she will have already begun to plunge, so that a propeller blade will at most appear for an instant, to stir the surface like the tail of a diving trout, before it disappears with the rest of the hull.

We have indicated the quality of the action which a rough sea may exert on the hull of a submarine trimmed by the stern while under way, but some investigation of its quantity is necessary before we can hold this to be a likely cause of the loss of submarine vessels in fine weather. Take, then, the case of a

submarine vessel 120 feet long, and assume the existence of a ground swell 50 feet long and in height only 24 inches from trough to crest, a swell which could not be considered large even for the purpose of manoeuvring submarines (this is the swell depicted in the figure) if the height of the waves were greater the effect would be greater, the length of the wave is not very material.

Under these circumstances it will be possible for as much as 20 feet of the vessel's backbone normally under water, with perhaps 40 cubic feet of hull, to be exposed at one time. This would mean a loss of buoyancy in the bow of rather more than one ton. The effect of the sudden imposition of one man's weight in the bow has already been pointed out, so that it may be conceived how extensive would be the effect of this exposure of the stem, which practically amounts to loading the bow with a weight of one ton. This loading would, it is true, reimmerge the bow within two seconds, but by that time it would be already dipping at the rate of nearly 2 feet a second, and within a second from the immersion of the bow the axis would pass the horizontal and the vessel would plunge. Now, before she can rise again, the horizontal rudder must not only stop the downward pitching, but must turn her bow upwards once more, and that in the teeth of her natural disposition to go on turning her axis at right angles to the direction of motion. This action must take some time, however strongly the rudder is applied, and the boat will attain a considerable depth before emerging again. This is no great matter if she is already finally trimmed for diving, with the hatches closed; but if she has been navigated with open hatches and small reserve of buoyancy, the odds are that on passing from smooth into rolling water the vessel's first pitch will also be her last.

We have said enough to indicate the dangers inseparable from the

present type of submarine boat. A submarine must necessarily have comparatively small reserve of buoyancy at any time; otherwise too much space will be required for the submersion tanks. When in process of trimming for diving or conducting operations this space must be still further reduced. It is also inevitable that a vessel of small buoyancy should be both transversely and longitudinally unstable, and, therefore, where immersion depends purely on the slope of the keel, extremely dangerous. But the degree of instability depends very largely on the form of the unsubmerged part of the hull. The most dangerous form of all is that at present prevailing. A convex or turtle deck undoubtedly makes for speed, whether at the surface or below, but it certainly makes for instability, since neither rolling nor pitching can much affect the position of the centre of buoyancy, and the metacentric height is, therefore, low. It is for this reason that a ship whose sides have a "tumble-home" above the waterline, like those of the modern French cruisers, rolls in such execrable fashion. On the other hand, a vertical side makes for stiffness, and a vertical stem and stern post for longitudinal stability. In ships of the Sunderland whaleback type, although the per cent. reserve of buoyancy is small, the stability is great, for the buoyancy is carried the whole length of the ship, and any pitching submerges a greater length of stem and adds a force of flotation which immediately rises the bow once more.

It might, perhaps, be considered with advantage whether a Doxford turret could not be usefully applied to the submarine, with a view to increasing its longitudinal stability. A much more effective improvement, however, would be to apply some artificial means of raising the bow when necessary, which must be far more powerful than the ordinary horizontal rudder. Middleton employs for this purpose a pair of ingeniously

constructed metal fins, which have an exceedingly powerful action, and can be swivelled round so as to raise or depress the bow, or merely to help the screw, as may be required. The inventor of this device prefers, however, to use two pairs of fins, one forward and one aft. By means of these two pairs the writer has seen a model submerged on an even keel with 9 per cent. reserve of buoyancy, or brought to the surface carrying a dead load of 9 per cent. Indeed, it is claimed for the fin system that a screw may very well be dispensed with altogether, but it is at least open to question whether from the point of view of efficiency the screw is not as far superior to the fin as wheels are to legs.

But even while the present form of submarine is adhered to, the dangers attending its use can be enormously mitigated by the adoption of reasonable precautions, and it is submitted that two rules which should be strictly enforced are the following:—

No vessel to be trimmed by the stern except at "lightest draught."

All hatches to be closed when under full speed.

One very valuable precaution has recently been adopted by the Admiralty. Every submarine boat carries outside the hull a float and line which can be detached from inside. In case of accident the float is sent up to the surface, affording at once an indication of the vessel's whereabouts, and a means of communication with the imprisoned crew. So far good, but no one is likely to forget that what the crew really desire is not merely to talk to the top of the water, but to get there. In the case of a wreck above water the crew naturally take to the boats, but in the case of a submarine, even if there were a submarine "dinghy" in at-

tendance, the difficulty would be to tranship. The crew can send up their float, but must remain below themselves.

It has been suggested that a detachable conning tower might be used, held to the hull by bolts capable of release from inside the tower. The real difficulty would be to make this form of attachment strong enough to stand the strain of full speed ahead under water; if, however, the device should prove practicable, it would be possible for the crew, passing into the conning tower, to close the hatch from inside, release the connecting bolts, and rise to the surface, to float there until help arrived. The device adopted by Middleton in the model above referred to is to carry in a socket in the hull a cylindrical life buoy capable of accommodating the crew and readily detachable. By this means the difficulty of attachment is overcome; but, on the other hand, the tender, carried really inside the hull, must be a frightful disturbance to the internal economy.

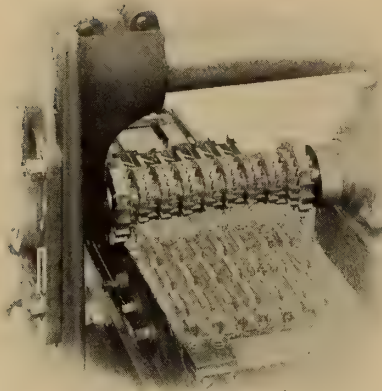
There can be no doubt but that the next few years will see very considerable advances made in the theory of submarine design, and in the details of the vessels and their accessories. At the same time, it seems probable that the situation of a submarine crew will never be any but a most perilous one, and certainly for the present it is eminently desirable that the use of these vessels should not be extended beyond the necessary minimum required for purposes of practice and experiment, and that the public who stay at home at ease should have at least some conception of the risks incurred on their behalf by those who go down under the sea in what their superior officers are pleased to call ships.

MODERN MACHINE SHOP REQUIREMENTS

AIDS TO RAPID AND ECONOMICAL OUTPUT

(Concluded.)

By Joseph Horner



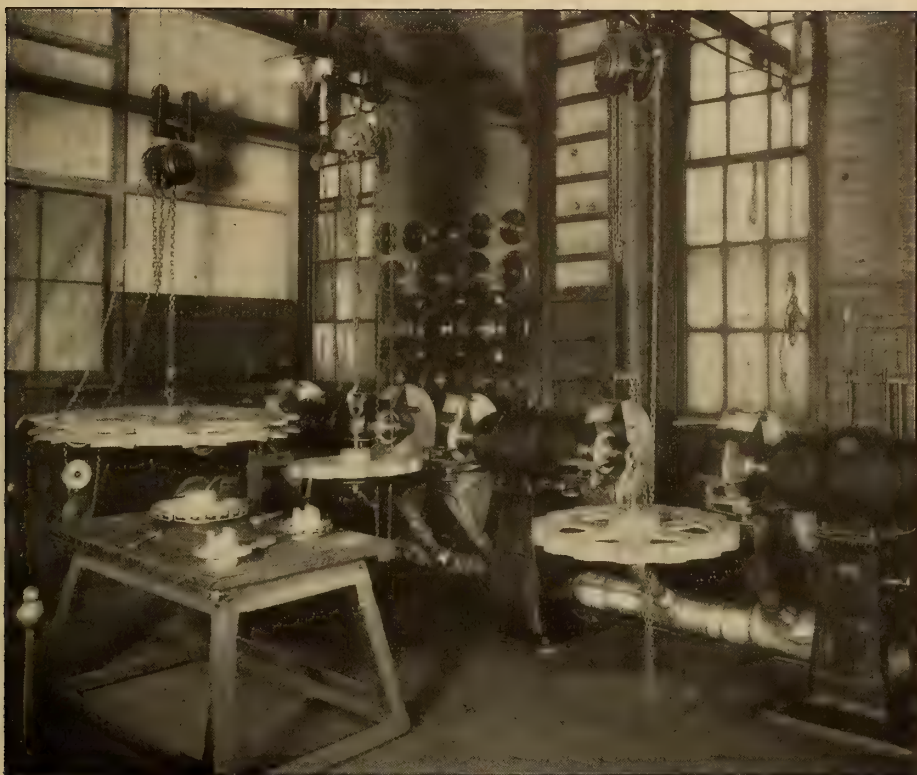
A MULTIPLE MILLING OPERATION

MANY machine shops are deficient in adequate provision for haulage and hoisting. The pulley blocks, slung from roof beams and trolleys running on the plain floors are still the principal aids. The overhead hand travelling cranes come next in favour. But the best aids of all,—the power traveller over the heavy machines, and the overhead trolley track over the lighter ones, and the narrow-gauge rails down the centres of machine bays,—form the equipment of the more advanced works. Objections are made to tracks on the ground of expense, that rails, standing up above the floor level, are occasions for stumbling, but chiefly that they do not go in and out among the machines, which a plain, wheeled trolley can do. The last is the most cogent objection. But the objection applies much more forcibly in the case of old

shops laid out in a heterogeneous fashion than in new ones arranged on the lines just indicated. The tracks can be used for bringing the work along the middle aisle adjacent to the machines, where castings and forgings can be picked up by the travelling cranes, or by hoists suspended from overhead, tracks so arranged as to serve all the separate machines within the sphere of their operations.

With regard to the standing-up of the rails above the floor, this can be avoided in three ways,—either by sinking the sleepers and rails until the top of the latter are flush, or by using wood blocking, sloping away from the outer edge of the rail to the floor level, and filling up the interior space between the rails with wood, or by using cast rails with flat tessellated plates, and sinking these level. Each method is adopted with floors of wood, and of cement. Machines out of reach of the central main tracks can be reached by running off-shoots from these, with or without turntables. Curves of long radius, 12 feet standard in the "Hunt" system, provide for easy movements of the trucks.

An alternative to these systems is the swinging jib crane running down the centre of a shop, and serving, by the radius of its jib, the machines to right and left. Each system is good, but each is better adapted to some conditions than to others. For heavy work the jib crane is very suitable, but the tracks and overhead travelling cranes are generally to be preferred. For light work the



GRINDING CHAIN WHEELS AT THE LINK BELT WORKS, PHILADELPHIA

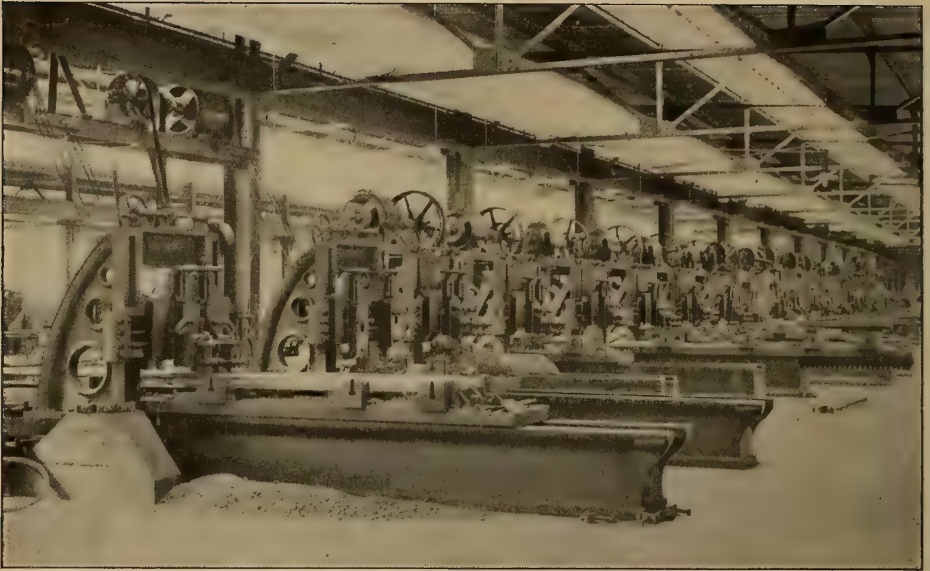
The wheels are driven by Northern Electric Co. motors, and fitted with exhaust fan connections to remove dust, and are equipped with overhead trolley and Triplex chain blocks

tracks, and light travellers, or the overhead tracks and pulleys are best. Latterly great advances have been made in the equipment of these overhead tracks with hoisting tackle, due to electric hoists. In the near future there will be a severe rivalry between the electric and air hoists.

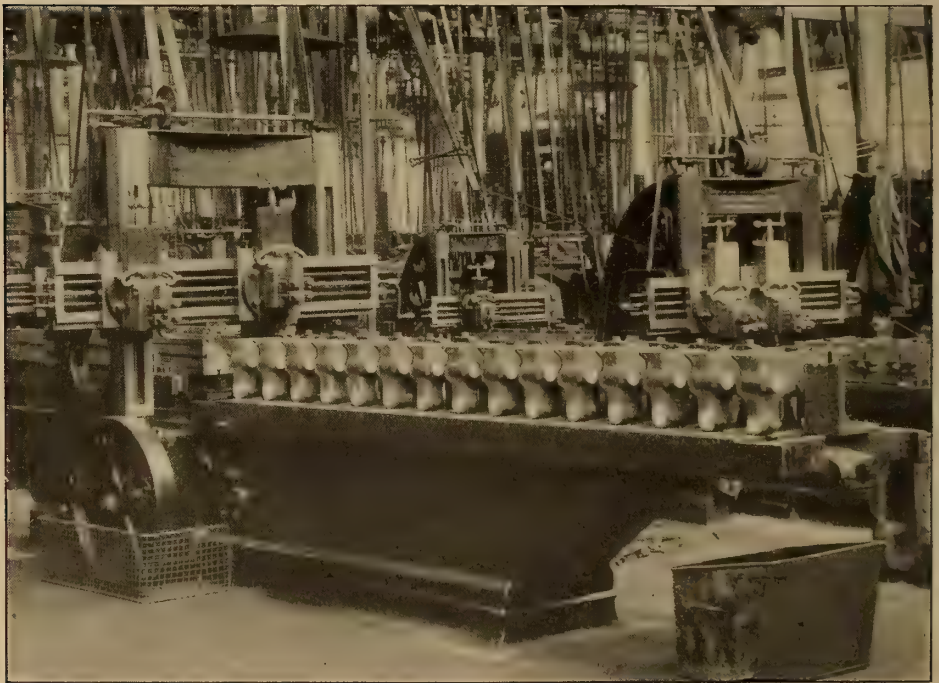
The general arrangements of a shop have much to do with methods of working. The difference is that between the orderly and systematic handling of work from beginning to end and the difficulties which bad arrangements throw in the way of the accomplishment of such results. The whole system of a shop is involved in this, though the subject has never received much attention until lately. As a result, large numbers of firms have either remodeled or rebuilt their works, solely with a view to the eco-

nomical location of machines and the best handling of materials and products.

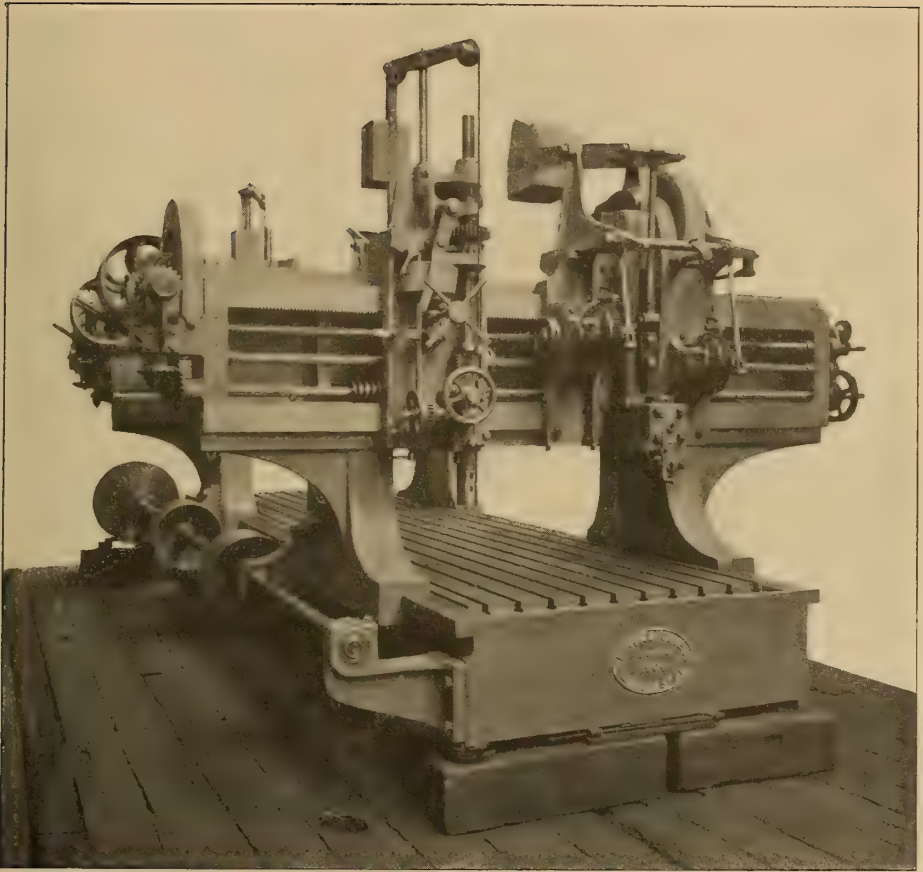
The arrangements of machine shops are much more carefully studied now than they were a few years ago. The older shops generally suffer from the disadvantage that they have grown up from small beginnings during a long course of years. Frequently existing buildings of irregular shapes and several stories high have been utilized. Heavy machines and light ones have been interspersed with the growth of the works, and heavy and light classes of work are thus carried on in juxtaposition, with all the disadvantages that result from such proximity. This lack of proper arrangement makes big work difficult to handle, prevents the use of



A LINE OF GRAY PLANERS DRIVEN BY ALLIS-CHALMERS MOTORS, AT THE SHOPS OF THE WEIR FROG & CROSSING COMPANY, EAST NORWOOD, OHIO



MODERN PLANING METHODS IN THE WORKS OF ALFRED HERBERT LTD., COVENTRY, ENGLAND



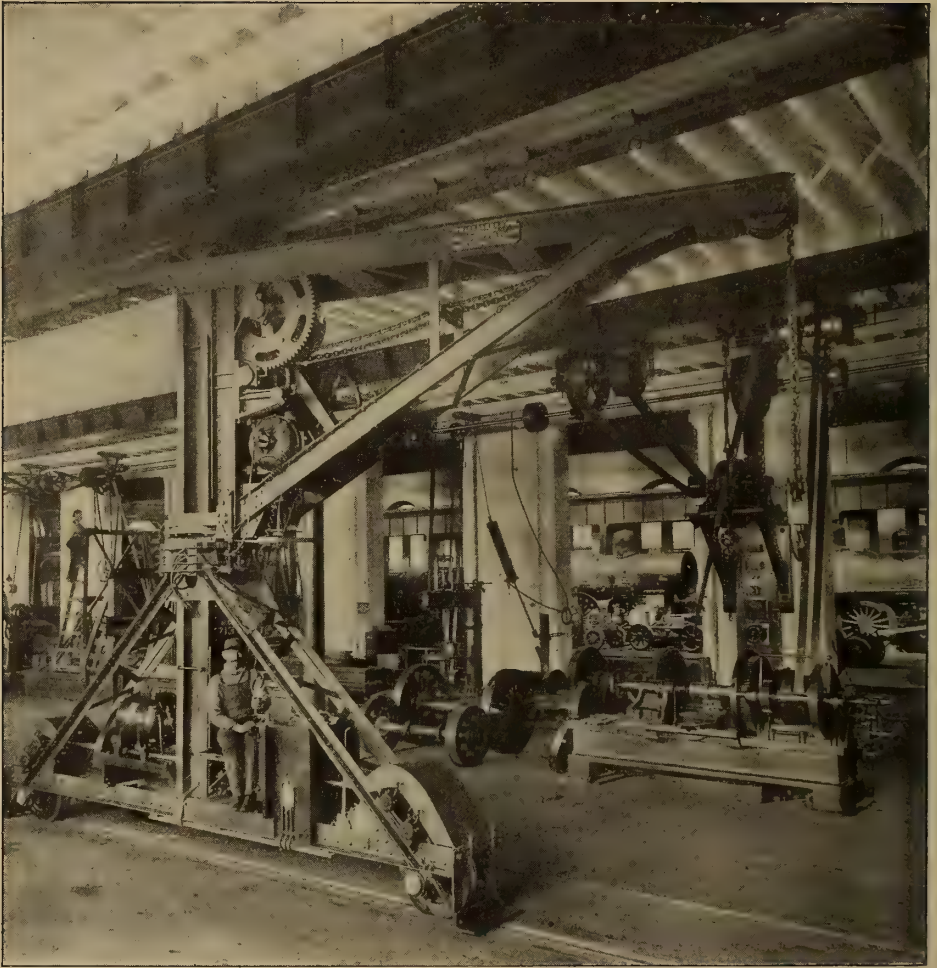
COMBINED SLOTTING AND DRILLING MACHINE FOR LOCOMOTIVE FRAME PLATES. CRAVEN BROS., LTD., MANCHESTER, ENGLAND

proper hoisting tackle, and jumbles up men and processes that ought to be kept quite distinct.

The newer works, profiting by such experiences, are built very differently. The ideal modern machine shop is rectangular in plan, with no angles and offsets. It may contain one floor only, or several floors, depending mainly on the class of work done, whether heavy or light. Generally, a modern factory is restricted to two floors in height, and, as a rule, the second floor takes the form of galleries, flanking and partly covering the ground area. Machines of a class are grouped together, the heavy machines separate from the light ones.

Departments are kept distinct either in separate shops or in different areas of large buildings, so that planing, milling, grinding, gear-cutting operations, and so forth, are kept apart from all others. The location of machines in parallel bays instead of in sheds irregularly built permits of the running of work in and out, down the centre on trolleys, preferably on rail tracks of narrow gauge.

In the modern shop we find that the appliances used are of vastly greater relative importance to the machine tools than they were formerly. An appliance is something that is not a machine, but which is subsidiary thereto, as a templet or a



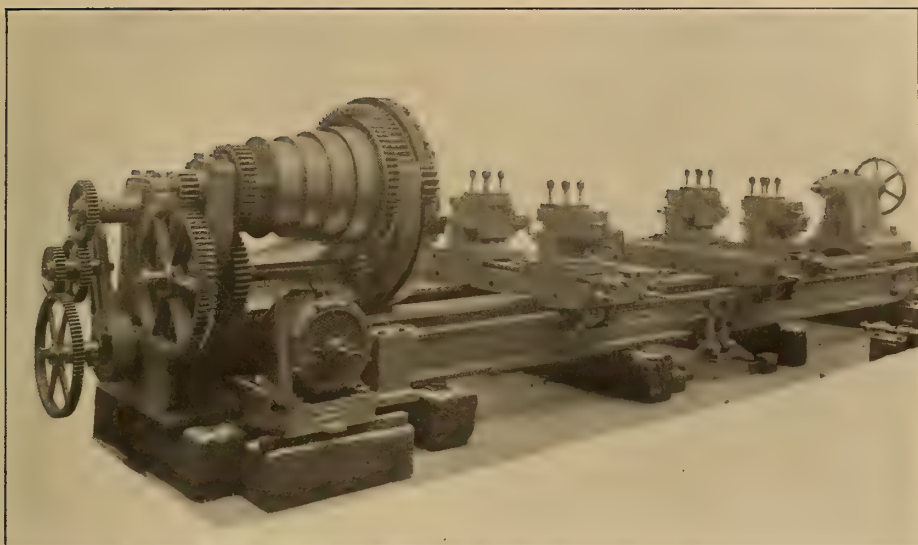
ELECTRIC-DRIVEN WALKING JIB CRANE, BY WILLIAM SELLERS & CO., PHILADELPHIA, AS INSTALLED IN THE SHOPS OF THE BALTIMORE & OHIO R. R. CO., MT. CLARE, BALTIMORE

jig,—something by which the work is facilitated, or by which accuracy is insured with the least labour and expense,—a short cut to results, which, without such aid, would be more tedious, and generally less reliable. The modern shop teems with appliances of these kinds; the older one did not. In proportion, too, as the management of a shop develops the system in which these find their fitting place, does the shop come into line with present competitive conditions.

The unmistakable tendency is now in the direction of the elimination

of hand work, and elimination of reliance on manual skill, on the fallible human element, and the transference of these to the less fallible, less variable, operations of tools and appliances. The appliances either save labour or they insure more uniform results, and, in the higher grades, interchangeability, while they are the most important factors in repetitive work.

The growth of jig work is one of the most remarkable facts in the best shops. It is sometimes hastily assumed that jigs are economically suitable only for work that is largely

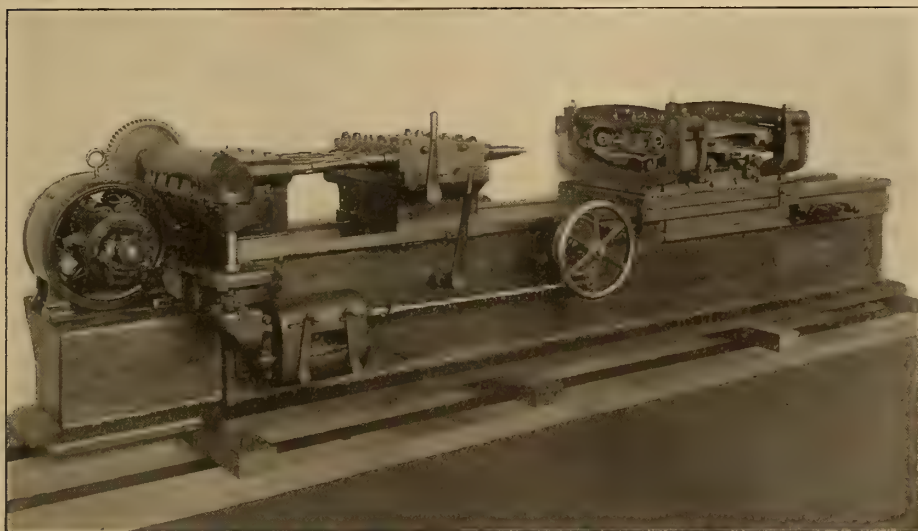


HEAVY ENGINE LATHE WITH NON-ROTARY TWIN SCREWS. HULSE & CO., MANCHESTER, ENGLAND

repetitive. Though they undoubtedly score best in such work, they afford lesser, but still invaluable, economies when adopted on a more limited scale. Like other systems, such as plate moulding and die forging, when introduced, their economies are less apparent on their first inception than at later periods when

stocks have accumulated, when the system has become familiar, and when the men and the arrangements have got into the swing of it.

The utilities of simple templets have long been, and are still, pretty well recognized in most shops. The making of templets for marking out or working by seems an instinctive



FIVE-SPINDLE BORING MACHINE FOR AUTOMOBILE WORK. BEAMAN & SMITH, PROVIDENCE, R. I.



VIEW IN FINISHED-WORK STORES ROOM. ALFRED HERBERT, LTD., COVENTRY, ENGLAND

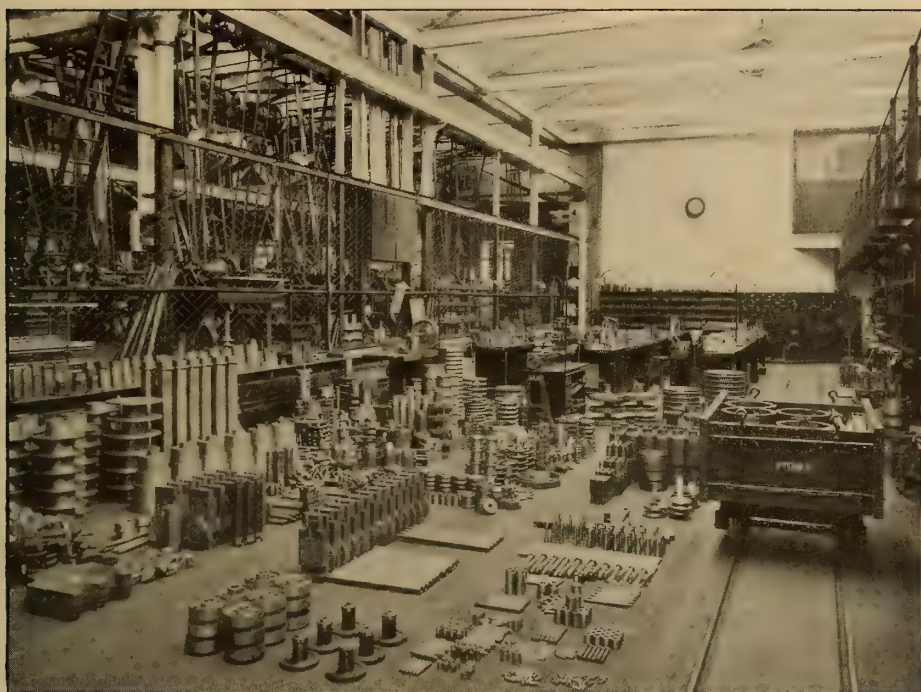
act on the part of the workman. But to embody the templet idea in a permanent jig seems too formidable a task to be undertaken lightly. And yet it is but an easy transition, for a jig in which work is held and tooled is but a magnified and highly perfected templet.

When jigs accumulate, they favour the standardization of parts. Much variation is made in parts for different motors, machines, and structures that is absolutely unnecessary. Designs of details need not vary to the extent they do. Minor measurements can be suppressed in favour of uniform measurements, when the differences are sixteenths, eighths, and often quarter inches or more, according to the class of work. The vagaries of draughtsmen should be made subservient to the economies of the shops, and variations in dimensions that are nearly alike should be prohibited. When these unneces-

sary and trumpery variations are eliminated, and the jig system is installed on a sensible basis, the work is cheapened, partly because labour is lessened, and partly because unskilled labour can, to a great extent, take the place of the skilled.

An essential part of this system is the proper stamping of all jigs, along with the registration of all jobs that are done by their aid. When they largely increase in number, they should be in charge of a department for storage and repairs. Jigs should not be altered for any alteration in work, but new ones should be made.

Two things which exercise a great influence in the character of the work done in the machine shop are perfect drawings and a good system of measurement. With regard to drawings, it is not possible to have these too full and complete in the information which they give. High-class finish is of far less importance



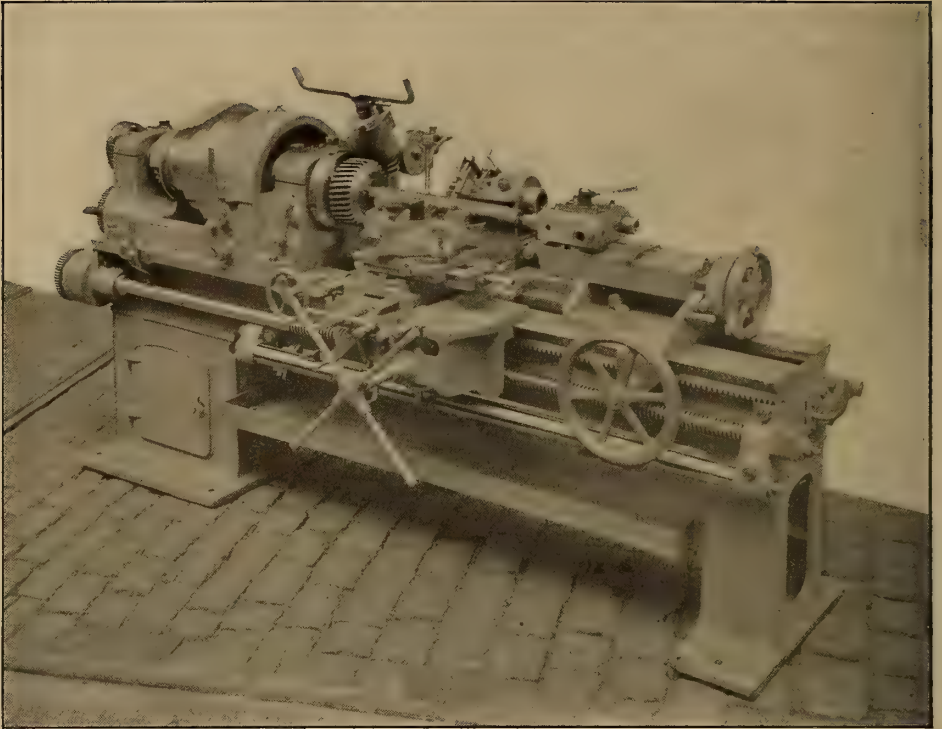
ANOTHER VIEW IN FINISHED-STORES ROOM. ALFRED HERBERT, LTD., COVENTRY, ENGLAND

than fullness of information. The machine shop, in common with other departments, has often been poorly served in this respect, much of detail having been left to be scaled, guessed at, or referred to the foreman. A workman's time is as valuable as that of the average draughtsman, and firms act injudiciously when they cut down the cost of drawing at the expense of the shops.

Everything that the workman should know should be on the drawing, even to every little radius and screw thread, stud, pin, collar, or class or grade of material. It should not be necessary to have to ask questions about the meaning of views, but complete sets of views and necessary elucidations ought to be included on the sheet, or sheets. Machine shop drawings should be for that shop only, and not be crowded with other work required by the pattern maker, smith or plater. Small scales should be avoided, and full size or large scales be adopted.

Portions that have to be tooled ought to be distinguished by conventional lines, or by words, from the black, untooled portions; and if limits are required, these ought to be clearly stated.

A good system of measurement must supplement good drawings. The use of the heterogeneous and nondescript rules and calipers cannot be tolerated in a shop where uniformity of product is intended. The mutual fitting of parts, which may be very good, is a different thing from mutual fitting to precise dimensions. If the absolute interchangeability of parts of the specialized shops is not practicable in the general shops, at least precise limits for fits for different classes of work can be adopted and manufacture be much simplified by them. This involves the substitution of fixed gauges for rule and caliper measurements. Special cases excepted, the work of lining out is excluded also for all except the larger work, be-



THE OLDFIELD PATENT CAPSTAN REST LATHE, BUILT BY CRAVEN BROS., LTD., MANCHESTER, ENGLAND

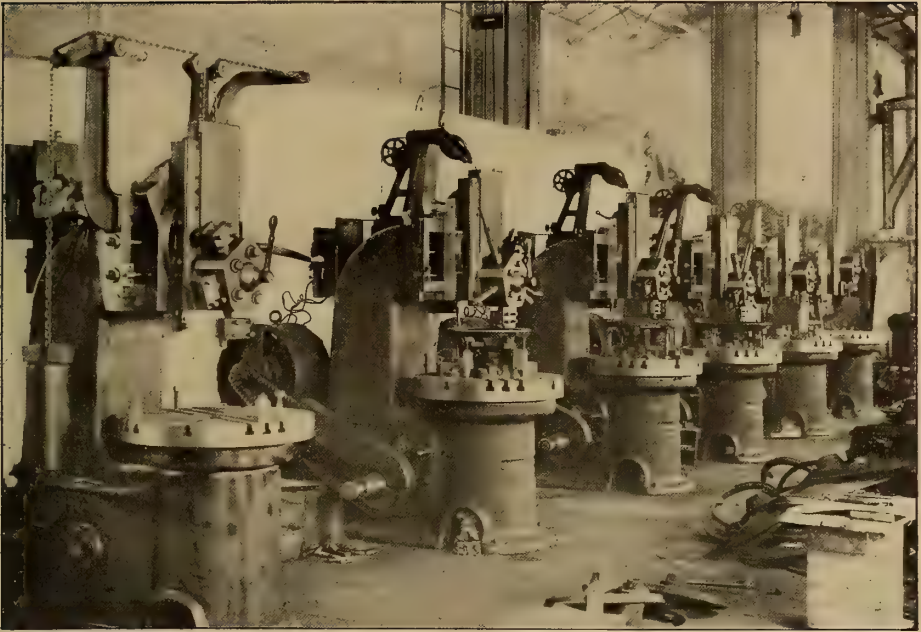
cause lining out must be done by rule and compass, except where templets are employed. But the work should be then checked on machining by fixed gauges.

The simplicity, accuracy, and permanent character of the gauging system is a recommendation to its adoption in any machine shop dealing with general or special work. But in view of economical considerations, the extreme accuracy of the fine limit gauges would be thrown away on the rough classes of work, because the cost would be unduly enhanced without any corresponding advantage; often, in fact, there would be disadvantage in working so closely.

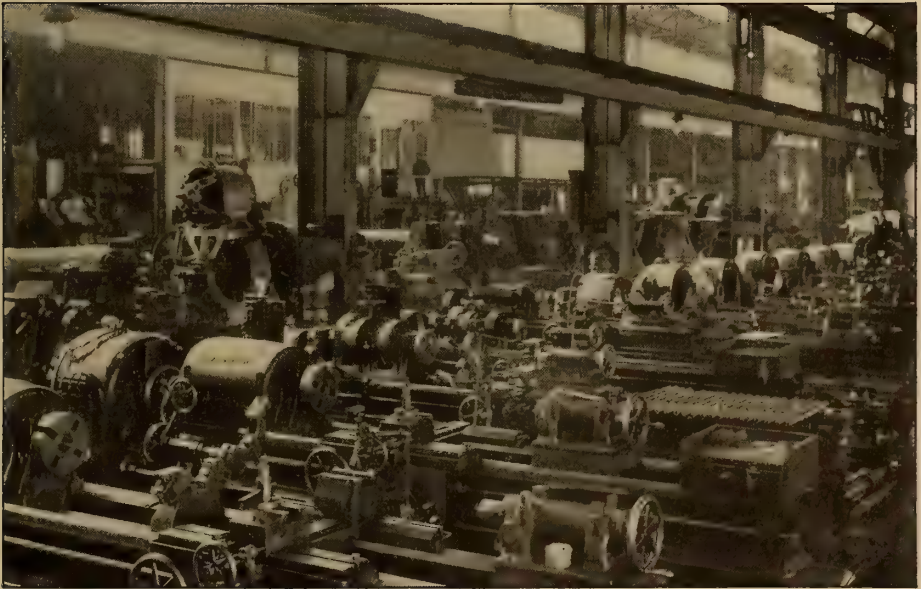
Doing work with a high degree of mechanical accuracy can easily be carried too far. Though whatever is worth doing at all is worth doing well, yet the application must be governed by the commercial condi-

tions that control manufacture. The judicious shop manager knows where to draw the line between good work, using the term in its proper application, and bad work. What would be the high-class workmanship in some products would be very bad in others. Illustrations in abundance will occur to the mind. There is, for example, no comparison between the accuracy of the workmanship required for a high-class machine tool, say a universal miller or a precision grinder, and a contractor's crane, or a donkey engine, or even a cheap lathe; or, say, between a self-lubricating, high-speed engine and a set of horse gear and pumps. The workmanship of the first, transferred to the second, would spell ruin to the firms who should put them on the market. The common shop terms, "good enough" or "near enough," therefore, apply here.

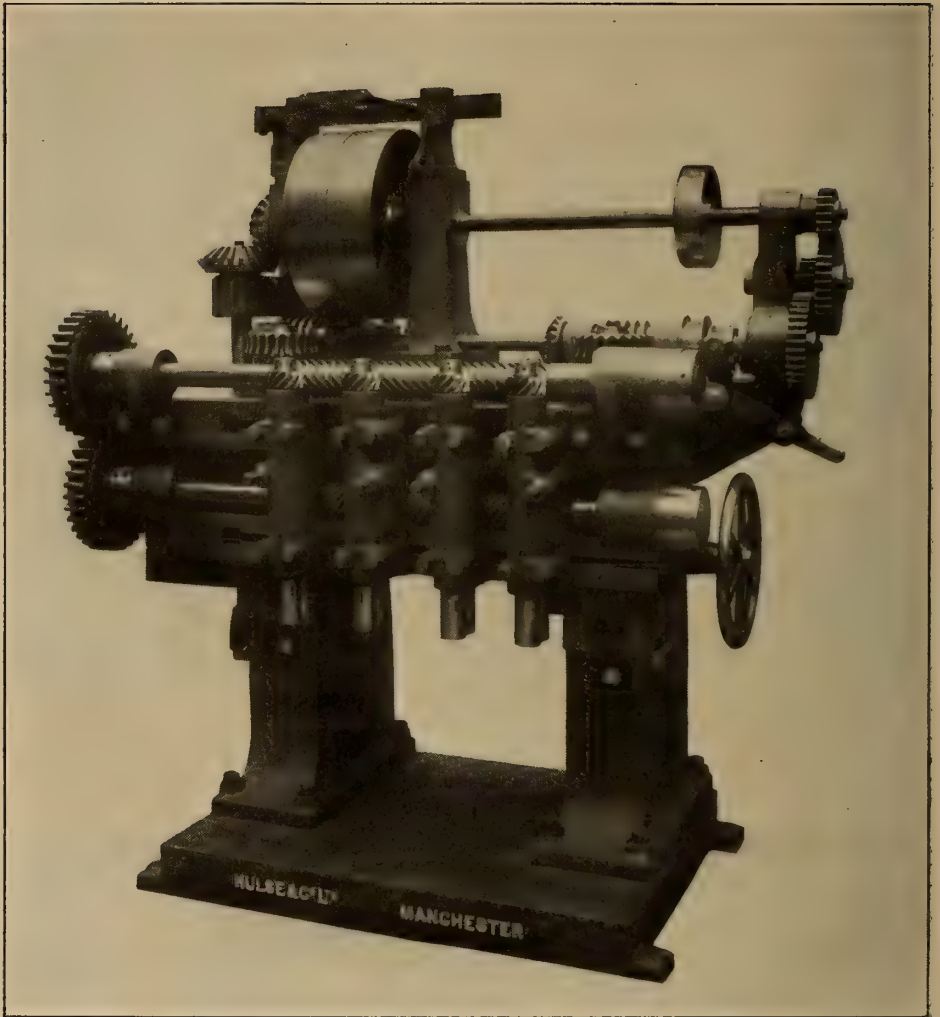
These relations apply also to the



COLBURN BORING MILLS AT THE ALLIS-CHALMERS SHOPS, MILWAUKEE



MOTOR-DRIVEN LATHES FOR HIGH-SPEED STEEL. ALLIS-CHALMERS SHOPS CINCINNATI, OHIO

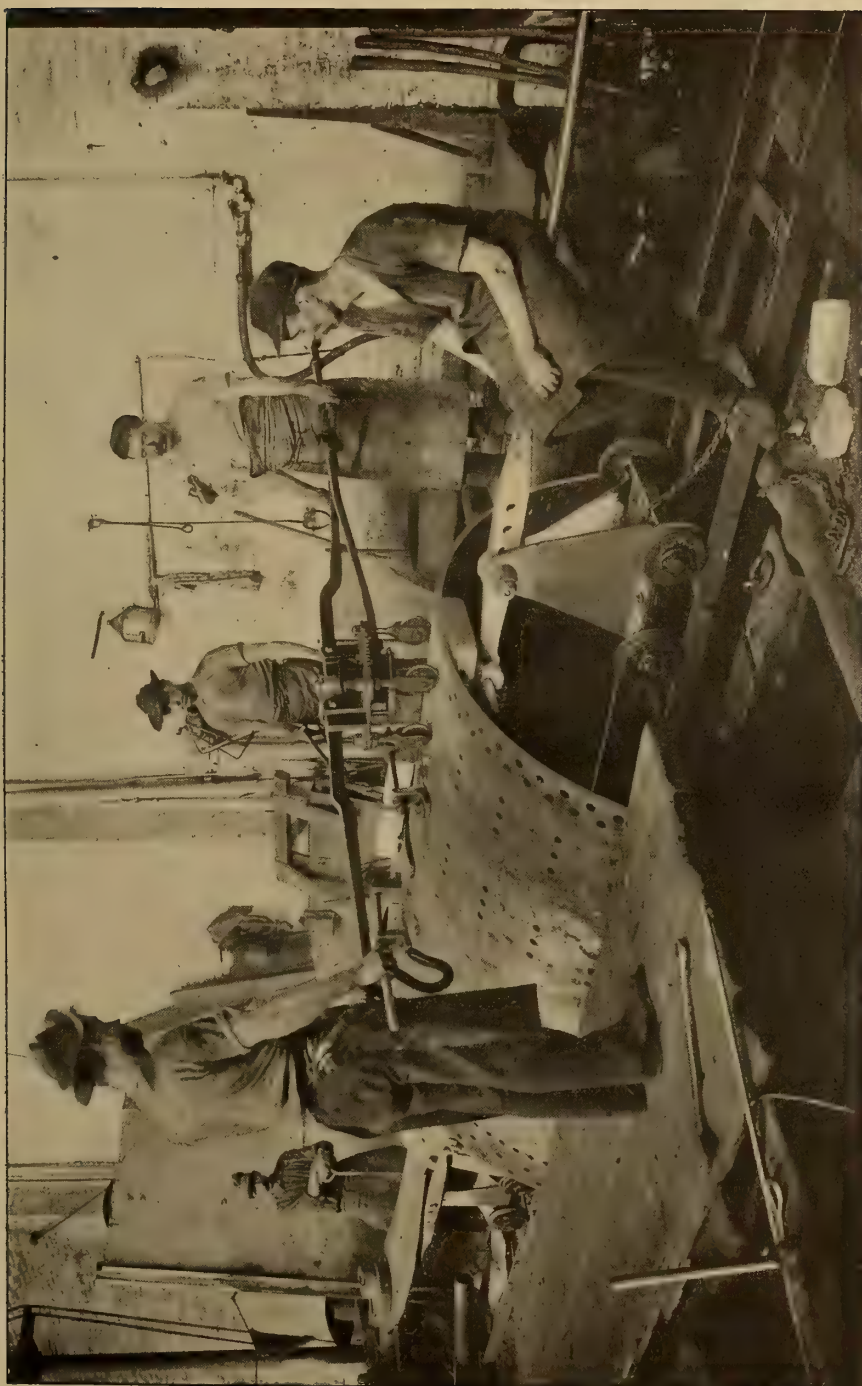


EIGHT-SPINDLE VERTICAL DRILLING MACHINE. HULSE & CO., LTD., MANCHESTER
Specially designed for work on wheel segments for electric tramcar work

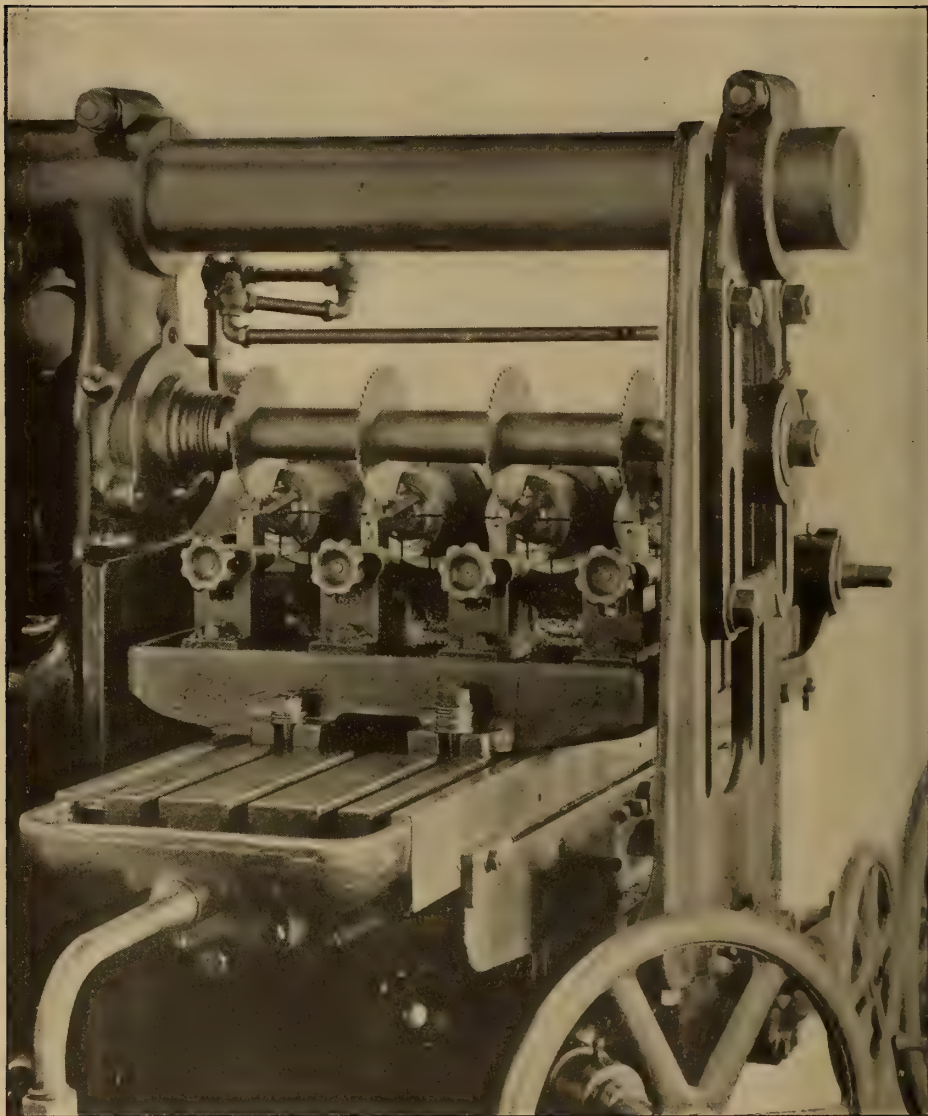
selection of machine tools for a given shop. The best tools for one are not in all cases the best for another. Good tools are, in any case, those which are the most suitable for the particular class of manufacture done by a firm. It is necessary to emphasize this strongly, because firms sometimes fall into the error of imitating others in which the governing conditions are different,—putting down certain high-class tools, and tools of a very special character, which are not so suitable for the

work of the imitating firm as some other kinds would be. As examples, may be mentioned the use of automatics when semi-automatics would be more suitable; of special gear-cutters when universals would be more adaptable; of special types of lathes and other tools for which there is not a sufficient volume of work to keep them employed; and of finer gauges when coarser ones would be better.

Many machine shops are lacking in cleanliness, order, and provisions



WELDING BOILER SHEETS BY MACHINE IN THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA, PA.

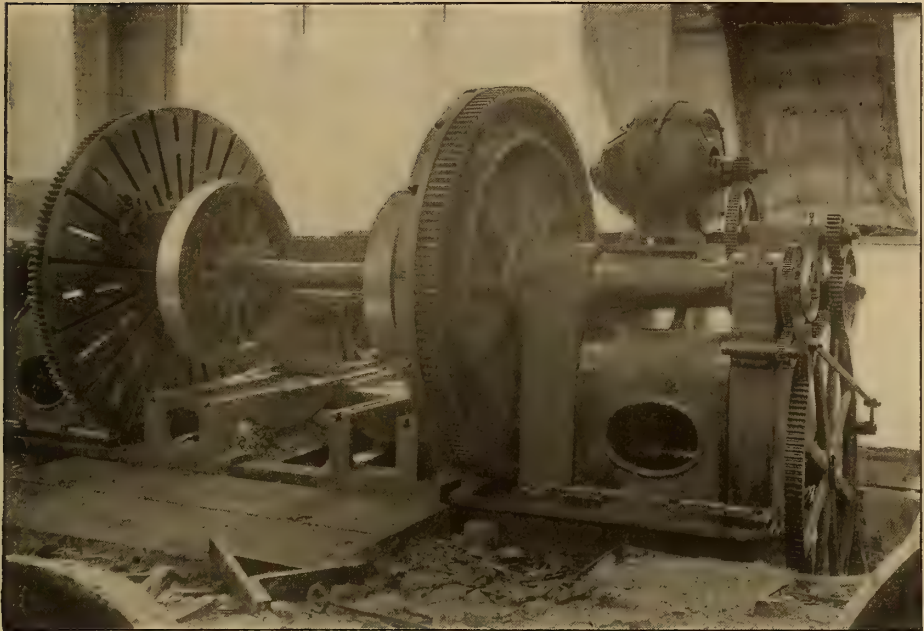


MULTIPLE SLOTTING OF COLLET CHUCKS. ALFRED HERBERT, LTD, COVENTRY, ENGLAND

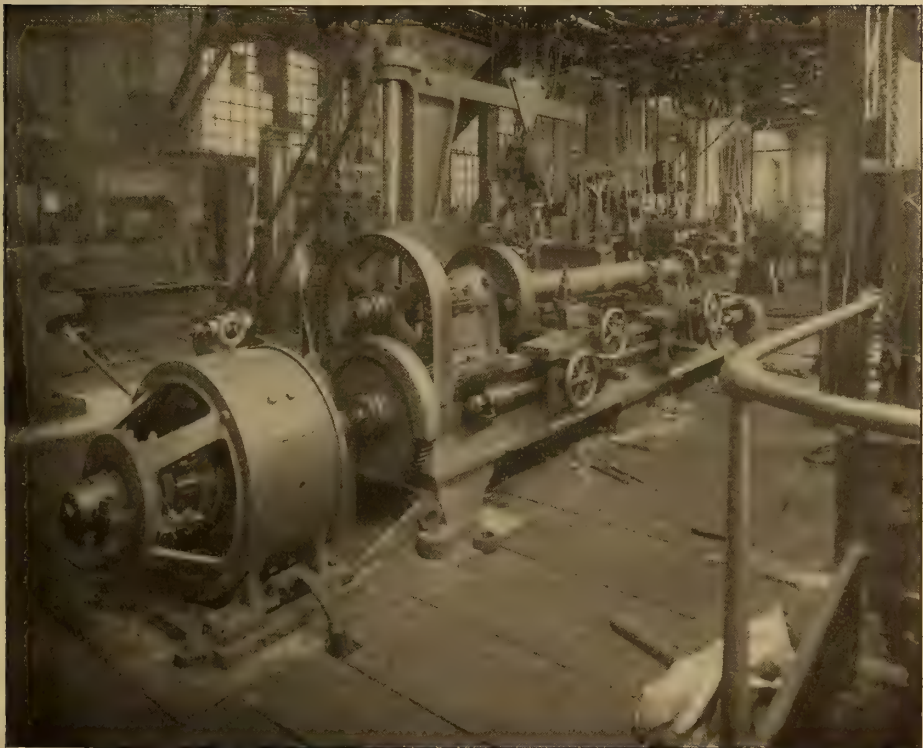
for safety. The latter are grouped with the former because they generally stand or fall together. An orderly shop is safer than one in which disorder reigns.

In the average shop it is generally considered that cleanliness is sufficiently observed if the machines are wiped down and tidied round about a quarter of an hour before knocking off on Saturday, regardless of

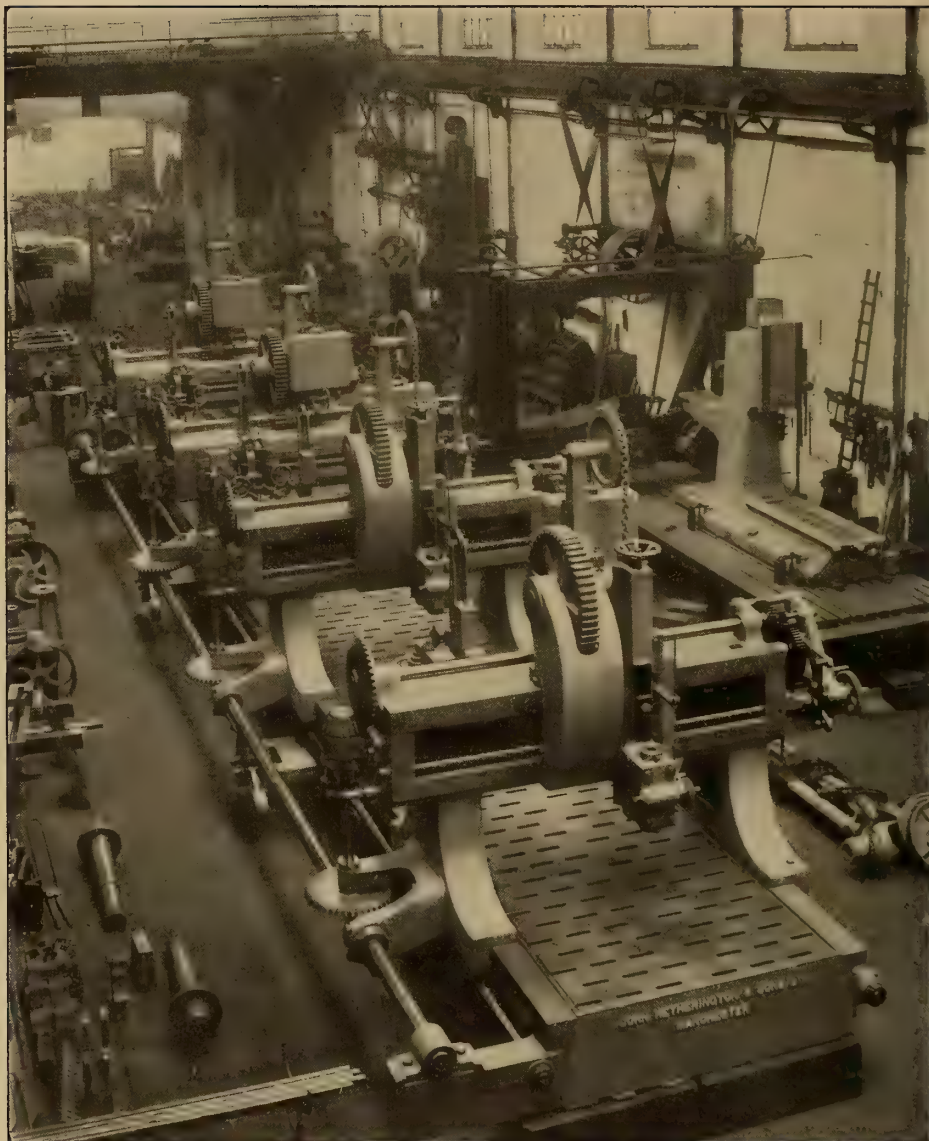
their condition during the week. All the week through they are covered with splatterings of oil and shoals of cuttings, while work lies around them in confusion, and the floor is saturated with dirty oil. No time or provision is allowed for cleaning, and no encouragement is given to its performance. It just depends on the individual attendant, whether he prefers a clean or a dirty environment.



A 60-INCH WHEEL LATHE, DRIVEN BY A 10-H. P. WESTINGHOUSE MOTOR



A NILES LATHE DRIVEN BY A 20-H. P. WESTINGHOUSE MOTOR

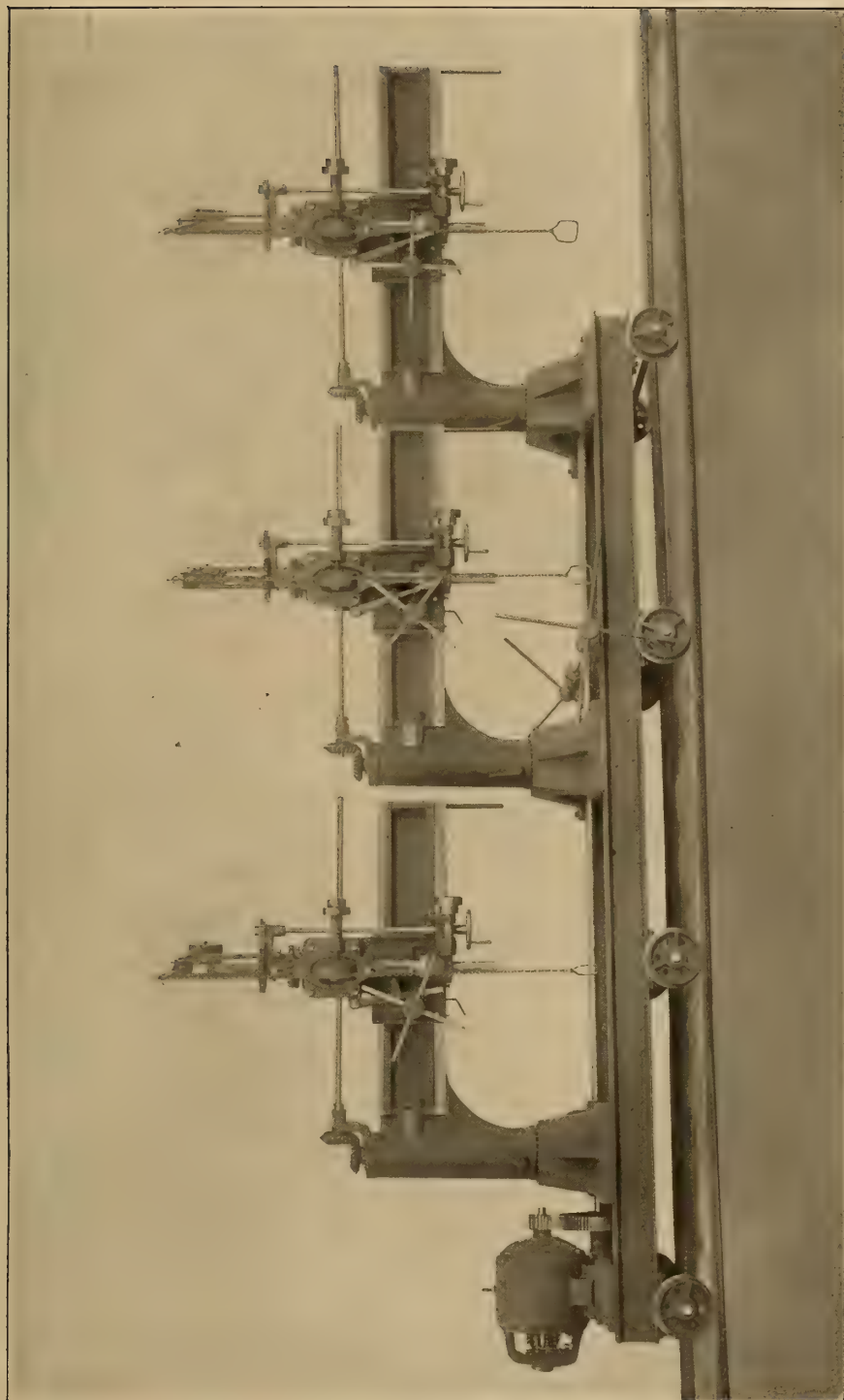


LOCOMOTIVE FRAME PLATE SLOTTING MACHINE. JOHN HETHERINGTON & SONS, LTD., MANCHESTER, ENGLAND

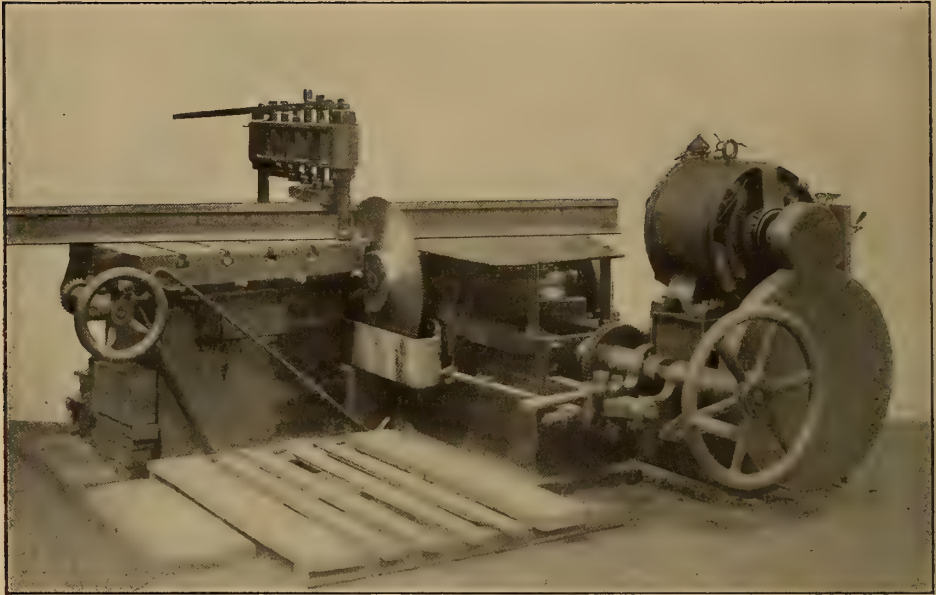
The heads have longitudinal and transverse feed, and the machine is arranged for electric driving. An important example of a modern special tool

Dirt and disorder are costly, but they will inevitably prevail unless the management takes the matter in hand from the beginning. Things are improving now, because many of the newer machines are designed with a view to prevent accumulations of oil and dirt. The waste oil and water troughs and trays which are a

feature in the best designs, though first put on only a few kinds of machines, are being applied to larger numbers. Removable trays for catching ships are becoming common. Cabinet designs and cupboards are made to receive tools. Racks and stands, fixed and portable, are made to carry the lighter classes of work



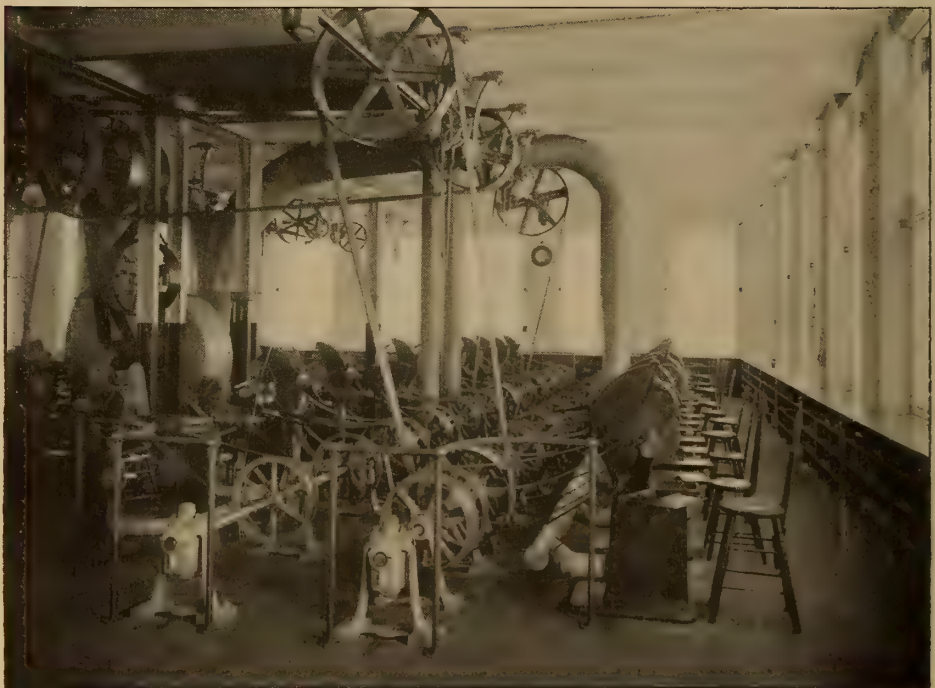
A PLATE AND GIRDER GANG RADIAL DRILL, MOUNTED ON WHEELS. BUILT BY WM. ASQUITH, LTD., HALIFAX, ENGLAND



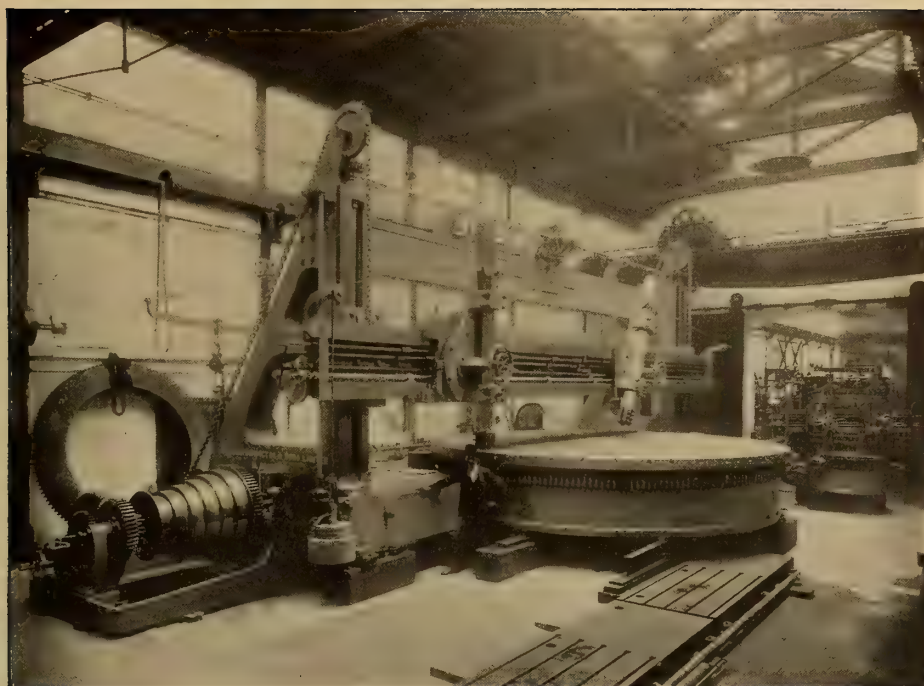
NEWTON COLD METAL SAW DRIVEN BY ALLIS-CHALMERS MOTOR

and prevent floors from becoming littered. Even waste paper bins are laid about in some shops. Non-ab-

sorbent wood is used for floors, to lessen or prevent saturations with grease and oil.



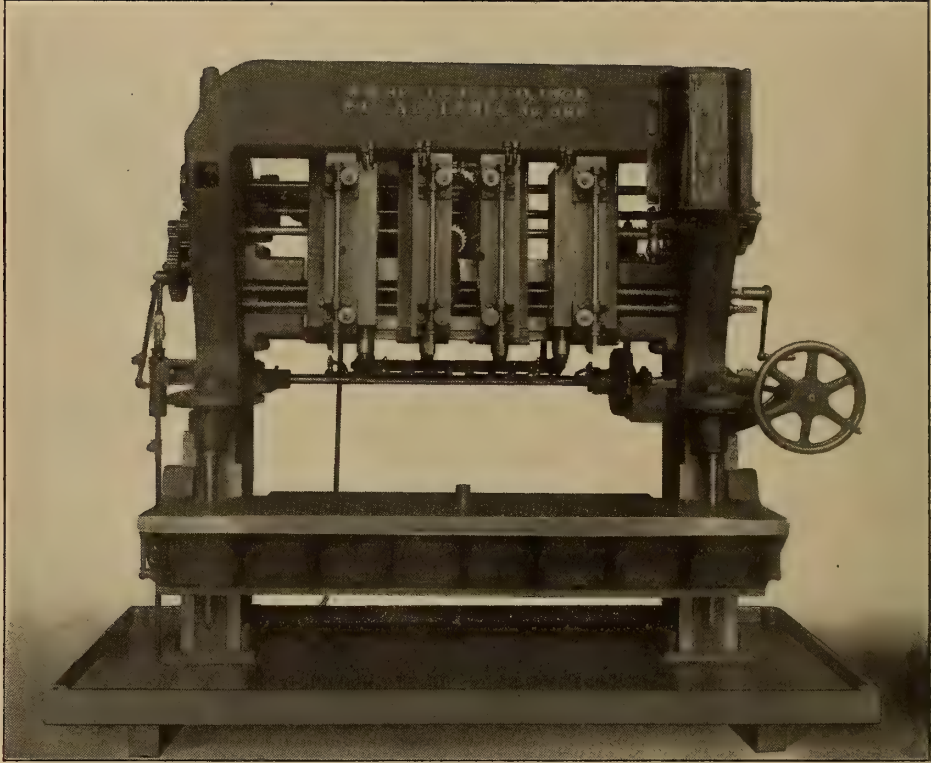
POLISHING ROOM, BROWN & SHARPE MFG. CO., PROVIDENCE, R. I.



HORIZONTAL TURNING AND BORING MACHINE. JOHN HETHERINGTON & SONS, LTD., MANCHESTER, ENGLAND



VIEW IN THE AUTOMATIC DEPARTMENT ALFRED HERBERT, LTD., COVENTRY, ENGLAND



EIGHT-SPINDLE MOTOR-DRIVEN DRILLING MACHINE. BUILT FOR THE GENERAL ELECTRIC CO. BY WILLIAM SELLERS & CO.

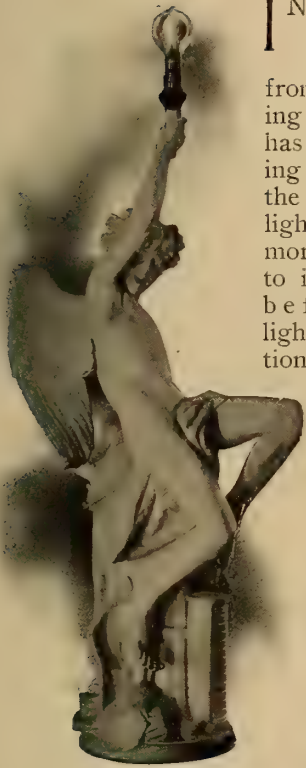
With regard to provisions for safety, we are becoming familiar with gears enclosed by cast-iron covers, with belts and gears protected by netting, and with safety guards for moving arms and connecting rods. Covers, netting, and guards have to be removed for cleaning and repairs, and they should be fitted so as to be readily detachable, because if much trouble is involved in replacing them, experience proves that this precaution will often be neglected. It is not enough to safeguard machinery, but the replacement of the guards must be insisted on. Protecting guards can be better fitted by the manufacturers of machines than by the purchasers. It is cheaper to make guards in quantity than singly, and better, neater designs can be secured in this way. As a single example, fitting cast-iron guards may

be mentioned. Good patterns with well-rounded outlines are not made cheaply. But the cost of these patterns, which should be made in iron or brass, is a mere trifle when spread over some scores of castings; hence the manufacturer is the proper person to make such guards. In a good many machines not a single gear is exposed, so that, apart from previous knowledge, one could only guess at the forms and functions of the gears by the outlines of the casings.

Though the foregoing may seem a lengthy list of lines on which machine shop economies are to be sought, it is not greater than is justified by facts. Much has been done of late years, but much remains to be accomplished before the average shops are abreast of the leading and modern establishments.

THE ARCHITECT AND THE CENTRAL STATION

By S. Morgan Bushnell



IN all large cities great buildings and enterprises are from time to time being started, and each has various engineering features related to the securing of its light, heat, and power more or less peculiar to itself. The problem before the electric light and power stations is to reach the proper parties in order, if possible, to connect these buildings to the central station electric light and power service.

In talking with the managers of some central stations, the writer has observed a note of discouragement, the idea of such man-

agers being that the erection of these buildings is always under the care of architects and engineers whose pecuniary interests are in the line of the installation of a power plant and its accessories, and who, therefore, could not be expected to give a fair hearing to the claims of a central station. It is doubtless a fact that a large proportion of the owners of big buildings look primarily to their architect for advice, not only as to the most economical style of construction, all things considered, but also in regard to the various details of operating and managing the building, among them the securing of

light, power and heat. It is a gross injustice to the vast majority of architects to think for a moment that the fact that the architect works on a commission and that his recompense is based on the cost of the building will materially influence him in his position as to whether or not an isolated plant should be installed. If this were true, then it would be to the architect's interest to have the work go to the highest bidder, so as to increase the cost of a building to the utmost extent. We know, however, that architects consider it to their interest to keep down, as far as possible, the cost of a building. Owners and real estate men are very careful before entrusting their work to a firm of architects to look up the records of these same architects in the various buildings which they have erected, and architects are frequently asked to show the cost per cubic foot of the various buildings constructed under their care. The showing made on these different buildings has a large influence in their securing additional business.

From this point of view it would naturally be to the interest of the architect to keep out the installation of an expensive, isolated plant, with its various accessories, as in this way he can make a better showing on the cost of the building.

The writer has had occasion to figure on a great many large buildings in the city of Chicago, and, before starting this article, wrote down at random the names of about twenty-five of the largest buildings that now secure their lighting and power from the Edison central service. Opposite each building was put the name of the party, or firm, who

was instrumental in awarding the contract to the company. To his surprise, he found that more than half of these contracts had been awarded through various firms of architects; a very small proportion were secured through direct negotiation with the owners; another small proportion was secured through the agents of the buildings, and a still smaller proportion secured through the consulting electrical engineer. While this condition may not hold true in other cities, there still remains the fact that the architect is a very important factor in determining the policy of any building which he designs. With this fact in mind, that the architect is the man to whom should be presented the comparative claims of a central station versus an isolated plant, let us take up for a moment the way in which this should be carried on.

Many a solicitor, having a well-founded belief in the economy of his proposition, is inclined to be disgruntled and disheartened because the architect does not immediately fall in with his views. It is well to remember in this connection that an architect's office is a clearing house for a great many different trades and occupations. The architect is beset and besieged on all sides. While there is one man claiming his attention in behalf of the central station service, there are twenty men who are arguing against central-station service and whose interests are along the line of the installation of the various types of machinery which go to make up the equipment of the modern electric lighting and power plant. In fact, this proportion is often larger than this, since for each type of apparatus, the engine, the dynamo, the boiler, etc., there are numerous competitors who, while they are competing against each other, are a unit in opposing the interests of the central station.

Many architects have become familiar with the cost of operating a building by means of its own plant,

while, on the other hand, the central station proposition is to them a comparatively untried field. It is, therefore, not only necessary to show the architect in general terms the inherent advantages of eliminating the power and lighting proposition, but it is necessary to give facts and figures which are thoroughly demonstrated. I say "thoroughly demonstrated," because in this field it is of the utmost importance that the proposition be kept on an engineering and scientific basis. The salesman may draw on his imagination once in presenting the proposition to an architect, and he may in this way secure one contract, but this very contract may be an expensive one for his company. Every architect puts up more than one building, and most of them several buildings every year, and it is very natural for him to judge of the future probabilities in a building from his experience in the past. Therefore, the solicitor who gives an accurate forecast of the cost of operating a building on central-station service puts himself in a very strong position for the negotiation of future business with the same architect.

In making a forecast of the amount of current to be used in any given building, there are two ways in which this estimate may be made. The first method is to take the number of lights in the building and all the different motors that are required for power and make a close estimate of the number of hours in which the light in different portions of the building will probably be left burning, and also the number of hours during which the motors will run. Adding all these different items together, the result will be the total kilowatt-hours consumed per day. Then, after making a separate estimate for the number of kilowatt-hours during Sundays and holidays, take the total number of days per year and the result will give the total kilowatt consumption per year. The second method is to have prepared in

the office a carefully tabulated list of a great many customers, showing the average consumption of power for the different classes of work and the average consumption of light in different classes of business. For example, in the city of Chicago the average consumption of light in a first-class office building where the light is used by the tenants on a meter basis is twenty kilowatts per year per 16 candle-power light.

In estimating the probable consumption of any new office building that is erected, this fact is a guide as to the probable consumption of light in the new building. In like manner, the cost of current for elevators, both for freight service and for standard office building service, can be tabulated, the cost of power for fans and for various classes of power showing the cost per month per horse-power installed. Taking this tabulated list and the number of horse-power installed in the new building, we can form an approximate estimate as to the amount of current which will probably be used in the new building, based on experience in other buildings. Then, taking these two estimates arrived at in these two different ways and comparing them, it will be possible to arrive at a fairly reasonable forecast of the consumption in any given building. This method has been followed for several years, and it has been very interesting to find how closely the actual consumption has tallied with the forecast.

In cases where a commercial establishment moves its business from one building to another a third method of estimating the consumption of current to be required can be used within certain limits. This method is to take an exact measurement of the amount of current required in the old building and use the net result as a guide to the amount to be used in the new premises. This method, however, must always be used with great care, as the difference in the amount

of space occupied by the business, the shape of the building, and other factors would be likely to greatly modify the result.

The matter of estimating the amount of current used in a building is of the utmost importance. The total consumption determines not only the rate which the central station can afford to make on the business, but it also determines the average cost per kilowatt-hour for an isolated plant. This fact may be easily seen by the following example:—Take a down-town business house operating its own plant; one of the first costs to be figured is the matter of fixed charges. The fixed charges are the interest, depreciation, repairs, etc., and these are based on the amount of the investment for engines, dynamos, boilers and other machinery. Assume that in making our estimate it is found that these fixed charges will amount to an average of two cents per kilowatt-hour on the estimated amount of current required. Let us suppose that it is found, after the plant has been started, that the current generated is just one-half of the amount that was used in the estimate; the result will be that the fixed charges would amount to just twice the amount estimated, or four cents per kilowatt-hour on the total amount of current generated.

It is a very common occurrence for owners to over-estimate the amount of current which will be required in their buildings. The owners of one of the largest buildings in the city of Chicago, a few years ago, made a contract for light and power, and their estimate of consumption was about three times the current which was actually used. Another large wholesale house figured their probable consumption at about four times what proved to be their requirements. A large theatre and office building recently made a contract in which they guaranteed a certain minimum bill. After a year's use of the current it was found that the guaranty was \$1000 too high. In

other words, the consumer frequently is willing to guarantee an amount which experience afterwards shows is greater than the sum total of the bill for current.

In figuring with an architect, it is necessary to take the matter up carefully, not only as far as the probable consumption of current is concerned, but to go into the merits of various types of apparatus, the various elements of cost which enter into the operation of a plant and into the comparative merits of the isolated plant and central station proposition.

It is well to draw up in typewritten form the comparative costs of the isolated plant and central station service. The estimate of the cost for central station service is, of course, very easy after the annual kilowatt-hour consumption has been determined. The estimate of the isolated plant operation, however, is considerably more complicated and requires a careful analysis, not only of the fixed charges due to the initial investment, but also the operating costs, etc.

These costs will, of course, include the fixed charges on the investment, such as interest, depreciation, rental value of space, damage to building from smoke, heat, vibration and other causes, insurance and taxes. Second, they will include the operating costs, such as labour, fuel, oil, water, removal of ashes, repairs, lamps, carbons, tools, waste, small miscellaneous charges, employers liability insurance, office expense in ordering material, taking bids, answering correspondence, etc.

The architect usually investigates such estimates with the keenest interest, inasmuch as the desire to reduce things to a scientific and practical basis is a marked characteristic of their profession.

Every great building that goes up in a city is the outcome of a long series of preliminary estimates and careful investigations as to the probable cost, expense of maintenance, income from rentals, etc., and it is natural that the man who has made

such careful estimates and forecasts of the future in regard to other details of a building should be deeply interested in the comparative costs of operating the mechanical and lighting equipment of a building.

The successful architect is always a broad-minded man, and it is this ability to see both sides of the question that should commend itself to the central station solicitor or engineer.

In many classes of buildings there is only a narrow margin of difference between the cost of operating an isolated plant and the cost of operating from the central station service. It, therefore, behooves the central station manager to get his prices on such a basis that the architect may clearly and conscientiously recognize the economy of his proposition, as the contract should be not only advantageous to the central station, but should also be economical to the consumer. If the central station engineers and managers will keep this thought carefully in mind they will find in the architect, not a man disposed to criticise and oppose their projects, but a man who can, from a high vantage ground of perfect impartiality, distinguish between the arguments for and against the central station service.

Every great architect is a man who has prominently before his mind the idea of a clean and beautiful city, and while he is often hampered in the construction of buildings by commercial requirements, he is ever striving toward the realization of the "city beautiful," the highest exponent of modern civilization.

The use of central station service with its absolute cleanliness is a step in this direction. Therefore, it simply remains for the central station to adjust and present properly the price of electric light and power in order to receive a most cordial reception from that class of men which is continually striving toward the highest ideals in the building of our great cities.



Current Topics

AMONG the recent events of importance in the engineering world probably the most noteworthy is the visit of the President of the United States to the Panama canal. This occurrence is of interest both for its direct bearing upon the future conduct of the enterprise and also because it is the first time that a President has ventured beyond the strict geographical limits of the country. The fact that Mr. Roosevelt made the voyage on a vessel of the United States Navy, maintaining daily telegraphic communication through space with the seat of government, adds somewhat to the scientific interest of the trip, since no former President could have depended upon the services of the engineer for such a purpose. The message in which the President sent his account of the visit to Congress also forms a notable document, both by reason of its contents and also because of the illustrations, mechanical reproductions of photographs of the work, an innovation in official communications of this sort possibly establishing a precedent of far-reaching importance.

A careful reading of the message

should be made by every one interested in this, one of the greatest engineering works now under construction in the world, since it is only by such a reading that the thorough nature of the inspection made by the President can be realized. Here we have space sufficient only to emphasize the salient points made as the result of the visit, these covering the essential features of the work in a most authoritative manner.

In the first place, the inspection was made in the worst month of the year, November having been found the most unhealthy time by the French, and well known as the period of heaviest rainfall. The Chagres River, the real bugbear of the whole problem, was at its flood, and all climatic conditions at their worst.

In his message the President approves fully of the decision in favour of the lock design for the canal, comments most favourably upon the vigour and efficiency with which the work is now being conducted, and advocates the use of alien labour, both West Indian and Asiatic, whenever found necessary. Maintaining that it is the business of the United States to dig the canal as efficiently

and quickly as possible, while maintaining humane methods, accepted standards of wages, and existing conditions of living, Mr. Roosevelt plainly says that the American workman in the United States has no concern whatever with the question as to whether the rough work on the isthmus, which is performed by aliens in any event, is done by aliens from one country with a black skin or by aliens from another country with a yellow skin.

The proposed contract system for the future conduct of the work is endorsed by the President as combining the maximum of advantage with the minimum of disadvantage. It is admittedly tentative, and may be subject to modification, but in no case is there to be any let-up in the rate of progress.

So far as administration is concerned, the President comes out plainly for a single responsible commissioner in the place of the present seven-headed body. There should be but one commissioner, with such heads of departments and other officers under him as may be found necessary, in addition to which there should be employed the best experts in the country as consulting engineers.

Thus we have the conduct of this great work, international in its importance, even though it be practically in the control of one nation, clearly laid out by the man to whom it has really been intrusted, and with such definite views, expressed in the most authoritative official manner, the world is positively informed as to the policy which is to be pursued, a policy which will give, in the shortest time, and in the most effective manner, the great waterway for which Europe, America and Asia have been looking for five hundred years.

IN his presidential address before the Institution of Civil Engineers, Sir Alexander Kennedy makes some most entertaining and instruc-

tive remarks about the engineer and his work. In the first place, he does not believe that our modern civilization, based so essentially upon mechanical methods, is necessarily the best of all possible civilizations on that account; but, accepting things as they are, he does believe that the engineer has done his best to accomplish the tasks which have been set before him.

Railways, steamers, telegraphs, telephones, electric-power distribution, automobiles, and all the rest, are all very well in their way, and the engineer is to be congratulated upon the manner in which he has devised and constructed these things. If, however, these had not existed, it does not follow that mankind would not have become as highly civilized, only the civilization would have taken some other, and perhaps more pleasing, direction. Taking things as they are, however, it is altogether proper that the relations between the engineering profession and the rest of society should be discussed before a professional institution.

Touching briefly on the question of education, Dr. Kennedy brings out a point of especial value to the young engineer, the desirability of working himself free from the leading-strings of youth. In engineering work, above all other occupations, it will be found that there are a number of ways of doing everything, no problem having a single solution, the same end being capable of approach by many different roads. This being the result of the experience of the engineer, it is surely he, above all others, who should set the world at large an example of tolerance and broad-mindedness in other matters.

Sir Alexander Kennedy has some instructive words upon the future of engineering, which are quoted at length elsewhere in this issue, and his entire address is filled with a broad spirit of philosophical tolerance upon many disputed questions in which the engineer is interested as a scientist, as a business man, and as a citizen.

DURING the past month there have been held in New York two important gatherings of engineers, the general meeting of the Society of Naval Architects and Marine Engineers and the annual convention of the American Society of Mechanical Engineers. The former organization, including, as it does, eminent men in the public service, as well as in private practice, enables the presentation of papers of much value at its yearly gatherings, while the meeting of the mechanical engineers, for the last time before entering upon the new quarters in the new building provided for the several societies by the generosity of Mr. Carnegie, proved notable both for the attendance and for the number and importance of the papers.

FOLLOWING the usual practice in the American Society of Mechanical Engineers, Mr. Taylor, the retiring president, made the subject of his address a matter with which he has been closely connected for many years, the art of cutting metals, with especial reference to the development of the modern high-speed tool steels. The length of this paper and the wide scope covered by it renders any comment here possible entirely inadequate. Rather may we discuss the method which made such a paper possible, a method involving the introduction of scientific processes of observation and deduction into the machine shop, and permitting the results to be recorded in such a manner as to make the information available for use elsewhere.

Broadly, Mr. Taylor and his associates set themselves to find solutions for three problems connected with the cutting of metals,—the character of the cutting tool, the proper cutting speed, and the best rate of feed for the purpose. The exhaustive nature of the inquiry will be realized when it is stated that the paper was really a book of about 250 pages, with twenty-four large plates, and that this treatise dealt with roughing

work only. The paper represented the results of between thirty and fifty thousand experiments, and an expenditure of nearly \$200,000, the work covering a period of more than twenty years.

In the matter of the nature of the tool, Mr. Taylor and his associates have developed what is now known everywhere as "high-speed steel," this really involving the discovery, due to Messrs. Taylor and White, of the fact that alloy steels containing tungsten or its equivalent, when raised to temperatures, far above those formerly considered excessive, are in reality rendered capable of sustaining much higher feeds and speeds than were considered possible. This discovery is really one of heat treatment rather than of constitution, and a number of alloy steels have been produced which respond to such treatment most effectively. The heat treatment itself, however, is practically the same for all, namely, the use of temperatures greatly above those at which the material was supposed to become "burnt" and ruined, but which, in fact, are essential to the proper tempering of the tool.

AN important development, or rather consequence, of the introduction of improved methods of cutting metals is their influence upon general machine-shop practice, machine-tool design, and management of labour. Studies made for the primary purpose of getting the best results out of the machine and the tool also involved the best results from the man. Even with the older methods of doing work, it soon appeared that the full capacity of neither man nor machine had been obtained, the results being from one-third to one-half what was readily attainable under skilled and interested supervision.

As the capacity of the tool and the machine have been extended by the improved treatment and design, so the capacity of the man has been developed by the introduction of

scientific methods of remuneration, enabling the employee to be benefited by the increased capacity of the whole plant, and practically giving him such an interest in the results as to enlist his active co-operation.

In like manner, the introduction of improved methods of cutting metals and of generally increasing the output of both machines and men has led to the scientific study of power development and application. The introduction of electric driving has reduced transmission losses to a large extent, and, at the same time, made it practicable to rearrange machinery with regard to operative conditions rather than with respect to power delivery. It has also made it possible to determine at will, and with a high degree of accuracy, the amount of power required to drive any machine or perform any operation, and thus placed in the hands of the engineer and the machinist a method of investigation not previously available except at much cost and inconvenience.

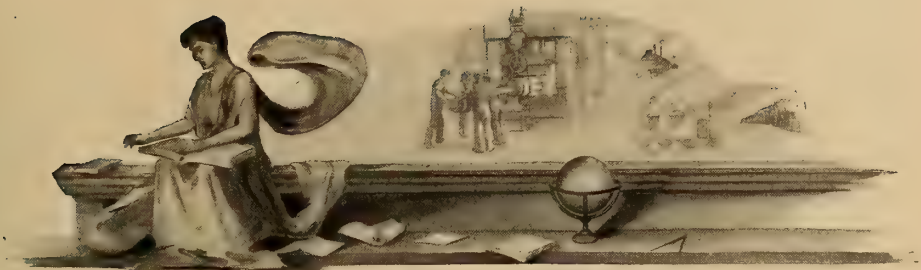
THE papers and discussions at the meeting of the Naval Architects and Marine Engineers covered several important fields in marine work, all important and each so extensive that but a glance can here be given.

Experimental investigations upon hulls and propelling machinery were covered by papers upon model-basin work, Professor Peabody giving his impressions of several such stations visited by him in the course of a recent tour. These included notes upon the Admiralty tank at Haslar, the tank of Messrs. Denny, at Dumbarton, and the basin of the Italian Government at Spezia, as well as the German stations at Charlottenburg and at Bremerhaven. Professor Peabody also examined the latest testing basin, that of Messrs. John Brown & Co., at Clydebank, but did not obtain access to the new station just completed for the French Government.

The work in the United States was well represented by the important paper of Naval Constructor Taylor, giving results obtained upon propellers at the model basin at the Washington Navy Yard. These investigations are discussed in the paper in detail, but it may be here mentioned that the results showed that there is little or no advantage found in giving any rake to propeller blades, and no reason appears for placing them other than perpendicular to the shaft. So far as thickness of blade is concerned, the tests showed a falling off in efficiency as the thickness increased, a point not previously determined in such a definite manner. The much-discussed question of the shape of blades was also investigated, the results indicating that the elliptical or even finer pointed blades are to be preferred, except for very fine pitches. In this connection it is most interesting to note that Mr. Taylor finds that the law of comparison holds very closely for such studies of screw propellers, and although this law is not absolute, yet it may be relied on with a good deal of confidence in considering model experiments as compared with trials upon full-sized screws.

NAVAL subjects, properly so-called, discussed at the convention were covered by papers on the development of armour and armament, on warship design, and upon the constitution of a modern fleet. To these may be added the paper upon the development of submarines, by Mr. L. V. Spear, and the communication of Mr. Spencer Miller relating to improvements in coaling ships at sea, to which we shall refer hereafter.

Other papers of interest related more especially to the design and performance of river steamboats of the type more particularly used in American river service, including the maintenance of high speed, and in the prevention of disastrous fires by suitable fireproof construction.



From Other Points of View

Work on the Panama Canal

From President Roosevelt's Message to Congress

THE main work is now being done in the Cuelbra cut. It was striking and impressive to see the huge steam shovels in full play, the dumping trains carrying away the rock and earth they dislodged. The implements of French excavating machinery, which often stand a little way from the line of work, though of excellent construction, look like the veriest of toys when compared with these new steam shovels, just as the French dumping cars seem like toy cars when compared with the long trains of huge cars, dumped by steam plows, which are now in use. This represents the enormous advance that has been made in machinery during the past quarter of a century. No doubt a quarter of a century hence this new machinery, of which we are now so proud, will similarly seem out of date, but it is certainly serving its purpose well now. The old French cars had to be entirely discarded. We still have in use a few of the more modern, but not most modern, cars, which hold but twelve cubic yards of earth. They can be employed on certain lines with sharp curves. But the recent cars hold from twenty-five to thirty yards apiece, and instead of the old clumsy methods of unloading them, a steam plow is drawn from

end to end of the whole vestibuled train, thus immensely economizing labour. In the rainy season the steam shovels can do but little in dirt, but they work steadily in rock and in the harder ground. There were some twenty-five at work during the time I was on the Isthmus, and their tremendous power and efficiency were most impressive.

As soon as the type of canal was decided this work began in good earnest. The rainy season will shortly be over, and then there will be an immense increase in the amount taken out; but even during the last three months, in the rainy season, steady progress is shown by the figures: In August, 242,000 cubic yards; in September, 291,000 cubic yards, and in October, 325,000 cubic yards. In October new records were established for the output of individual shovels, as well as for the tonnage haul of individual locomotives. I hope to see the growth of a healthy spirit of emulation between the different shovel and locomotive crews, just such a spirit as has grown on our battleships between the different gun crews in matters of marksmanship. Passing through the cut, the amount of new work can be seen at a glance. In one place the entire side of a hill had been taken out recently by twenty-seven tons of dynamite, which were exploded at one blast. At another place I was

given a Presidential salute of twenty-one charges of dynamite. On the top notch of the Culebra cut the prism is now as wide as it will be; all told, the canal bed at this point has now been sunk about 200 feet below what it originally was. It will have to be sunk about 130 feet further. Throughout the cut the drilling, blasting, shoveling, and hauling are going on with constantly increasing energy, the huge shovels being pressed up, as if they were mountain howitzers, into the most unlikely-looking places, where they eat their way into the hillside.

Engineering Evolution

Sir Alexander Kennedy, Before the Institution of Civil Engineers

WHAT of the future of engineering? Is it possible to predict, or even to indicate with any approach to certainty, the lines on which the engineering work of our grandsons is likely to be carried out? I fear that it is not possible. I have tried to think out whether there is anything in mechanical science corresponding to the "survival of the fittest," any definite and traceable lines along which evolution takes place, or, indeed, anything which can rightly be called "evolution" taking place at all. If only this did occur, we might be able to recognize its direction, and by such recognition help in bringing about a sort of artificial selection which,—as with plants and animals,—might prove a wise acceleration to the slow action of unaided natural selection.

To a certain limited extent a traceable process of evolution does apply to both machinery and structures,—with the latter only to a very limited extent indeed. It cannot be said, I suppose, that we can to-day make finer masonry structures,—structures more perfect either from an artistic or a scientific point of view,—than the Romans could, or the Greeks before them, or the Egyptians long before either. The only great devel-

opments in structural work have come about through the use of new materials and new methods for handling them. Concrete, on the one hand,—which in its present form may be considered new,—and steel on the other hand, especially, have entirely altered our structural methods. It is not difficult to trace in the designs of the steel structures of the last twenty-five years, following on the iron structures of sixty years ago, fairly continuous modifications in the direction of adaptability of means to end,—i. e., in the application of improved and extended scientific knowledge. But the real evolutionary difficulty,—and, therefore, the difficulty of saying anything about the future,—is the question of the origin of species, just as in biological matters. Biologically one form changes into another with a gradation in time which is almost geological. We cannot find of any species a time immediately before which,—immediately, that is, within 100,000 years,—nothing very closely resembling that species existed. With us it is different. In structural works we may say that iron or steel and masonry represent different "species." But yet you can fix a date before which there were no wrought-iron bridges, or even attempts at them, and fifty years after which there were thousands. As a species, steel structures may certainly be said to represent a "separate creation." The years taken to develop iron and steel-making machinery, and to develop the methods for using the material, are so few, historically, as to represent only an instant in terrestrial time. And before them the centuries went on one after another without bringing about the least indication of what was to happen in the fullness of time.

It would appear as if "invention," whether in the popular acceptance of the word, or in the sense of painstaking working out directed to an object of immediate importance, constitutes such a disturbing influence in mechanical or engineering evolution

that it is useless to attempt prophecy on evolutionary lines.

But once discovery, or invention, or patient investigation has created its new species, be it material, or method, or machine, the thing itself falls inevitably into line, and has to submit to the operation of certain general tendencies, which people are fond of calling "laws." It must either work out its success along lines which can be fairly well predicated, or it will fail to work out any success at all, fail to fall in with the general scheme of the (mechanical) universe, and disappear.

Warship Building Capability

Sir William H. White, in the London "Times"

RELATIVE naval power and standing are not governed, nor, indeed, much affected, by the time occupied in producing one or two ships even if they be of the most improved types. The really important question to which an answer is required is, Does Great Britain continue to possess a superior productive capability in warship building which will assure supremacy at sea? That supremacy requires the maintenance of stronger and more numerous fleets; it does not rest on the possession of single ships of great individual power. A *tour de force* such as the completion of the "Dreadnought" in a year from the laying of her keel,—probably about a year and a half from the time the dockyard received information which enabled the work of preparation to be commenced,—is a remarkable illustration of what can be accomplished by organization and command of labour at Portsmouth Dockyard, associated with the utilization of the resources of private firms, and the determination to give precedence to the work on and for the particular vessel. It does not represent the conditions of practice on a large scale. The German naval authorities

no doubt could make a similar display on a single ship, and "organize victory" on similar lines if they cared to do so. They are not likely, however, to be tempted into a useless competition, involving very heavy financial provision in particular periods; they have preferred the maintenance of steady and systematic progress, and the fairly uniform expenditure obtainable when periods of three years are taken to build each battleship or large cruiser.

The organized co-operation of many and varied industries, besides the shipyard and marine engineering factory, is essential to the completion and equipment of modern warships. Everyone has heard of ships waiting for the delivery of armour, guns, and gun-mountings; but delays are not unknown also in the delivery of structural materials, auxiliary machinery, electrical equipment, and other accessories essential to the advancement of work and completion of ships for service. Unless the output and capability of establishments devoted to the manufacture of all the items which are requisite for completion of warships are properly proportioned to the programme of shipbuilding,—so that the several parts may be ready at the dates required for their ready incorporation into the structure, fittings, or equipment of the ship,—delays and increased cost will be inevitable. A modern warship is recognized to be a "box of machinery," complicated in its internal arrangements, and not easy to understand in its finished condition. Besides the propelling apparatus with its enormous weight and power, a great number of powerful engines have to be introduced into the protected positions deep down in the hold; and, when all that is possible has been done to minimize dimensions and weights, it still remains true that many cumbrous and heavy parts have to be passed down into places in the structure that are difficult of access, and there erected into complete machines.

FRANK H. TAYLOR

A BIOGRAPHICAL SKETCH

ENGINEERING and commercial administration are coming into closer and closer relations, and an examination of the careers of men who have attained high rank in the great industrial establishments of the United States, as well as of other countries, will show the extent to which men of university training, as well as of engineering experience, are filling stations directly concerned with administration.

A notable example of this relation between engineering and economics appears in the case of the Yale & Towne Manufacturing Company. Linus Yale, the inventor of the Yale lock, was well known as one of the most ingenious mechanics and inventors of his day. His early partner, Mr. Henry R. Towne, for many years past the president of the company, is himself an eminent engineer, past-president of the American Society of Mechanical Engineers, and, at the same time, prominent in commercial, municipal, and national affairs.

A further instance of this combination of scientific and business ability appears in the person of Mr. Frank H. Taylor, recently elected vice-president of the same company, and whose portrait forms the frontispiece of this issue.

A native of Cincinnati, Ohio, Mr. Taylor was graduated from Haverford College, near Philadelphia, after which he entered Harvard University, from which institution he received the degree of A. B. in 1877.

After leaving college Mr. Taylor began as an apprentice with the George Fox Starch Company, of Cincinnati, Ohio, reaching the position of superintendent of the factory.

In 1882 he left Cincinnati, going to Philadelphia, where he organized the Belmont Iron Company, this firm conducting an extensive busi-

ness in architectural iron work and construction. Mr. Taylor occupied the position of treasurer of this company at first, and subsequently held the office of president; but in 1890, after the plant of the Belmont Iron Company had been destroyed by fire, he accepted the position of manager of the Philadelphia branch house of the Yale & Towne Manufacturing Company. At that time the Yale & Towne Manufacturing Company was actively engaged in the manufacture of cranes and heavy hoisting machinery, in addition to the various lines of chain blocks, as well as their extensive products in locks and hardware, and Mr. Taylor proved himself most successful in handling this varied line of mechanical products. After seven years in this connection Mr. Taylor left Philadelphia, removing to Pittsburg, and, entering the service of the Westinghouse Electric & Manufacturing Company, he took an active part in the development of the sales department, filling successively the positions of fourth vice-president and second vice-president, which latter office he held for three years, resigning in 1906. He now returns to the Yale & Towne Manufacturing Company, having been elected, as above stated, to the position of vice-president, in which capacity he will enter into close relations with both the manufacturing and commercial sides of the work of the company, being closely associated with the administrative work of the president.

In addition to the position of vice-president of the Yale & Towne Manufacturing Company, Mr. Taylor is a director of the Westinghouse Electric & Manufacturing Company, a director of the Provident Life & Trust Company, of Philadelphia, and one of the trustees of the Engineers' Club, of New York.





PHOTO BY ROCKWOOD, NEW YORK

GANO S. DUNN

CHIEF ENGINEER OF THE CROCKER-WHEELER COMPANY, AMPERE, N. J.

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CASSIER'S MAGAZINE

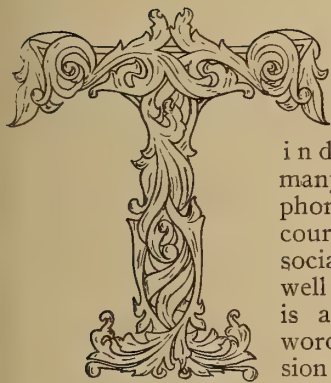
VOL. XXXI

FEBRUARY, 1907

No. 4

WIDENING APPLICATIONS OF THE TELEPHONE

By William Maver, Jr.



HE utility and convenience, in fact one might say the absolute indispensibility, in many cases of the telephone in the ordinary course of business and social life, are now so well established that it is almost a waste of words to give expression to the statement. It is almost proverbial

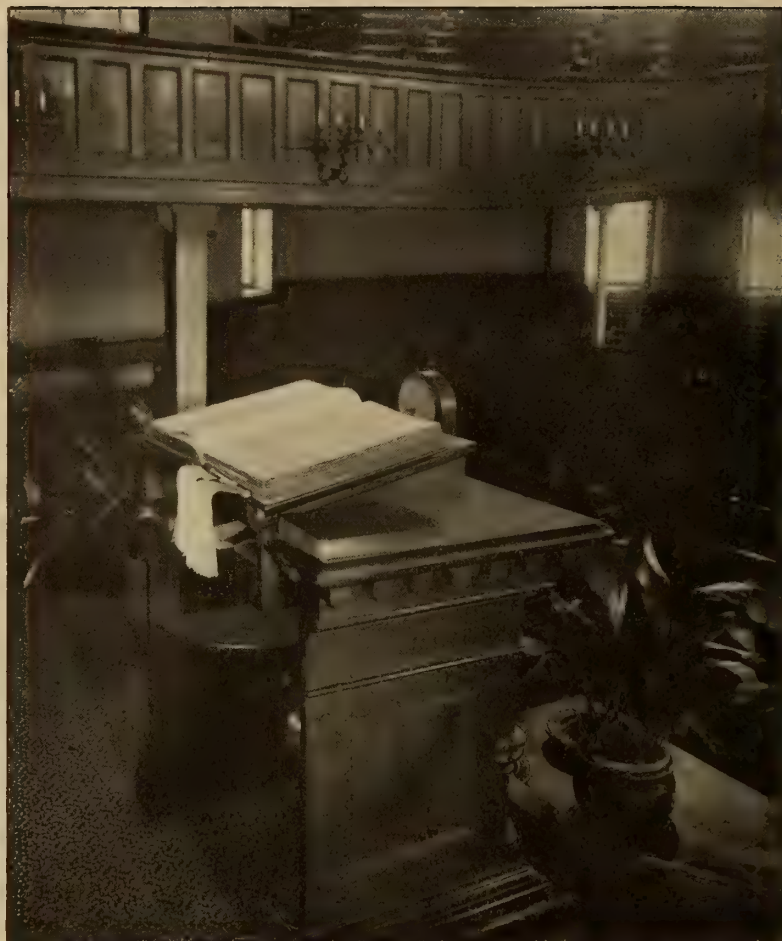
that the man, nowadays, who has not the telephone in his business establishment is, with rare exceptions, virtually out of business. The legend, "Don't travel, telephone," may not be poetical, but the advice is certainly sound, and it is not too much to say that the telephone practically lengthens men's lives by conserving the time that would, without its use, be spent in travelling.

Furthermore, besides lengthening life's span, the telephone adds greatly to the comfort and pleasure of social and domestic life. In untold instances its use avoids anxiety, as when unexpected engagements or detentions have prevented the member of a family from being at his or

her accustomed place in the home circle. It is true that at such times resort might be had to the telegraph, but unfortunately there is no assurance that the telegram will reach its destination in time to ward off anxiety as to the cause of absence. Indeed, the great advantage of the telephone over the telegraph is that it puts the user into direct communication with his correspondent and gives him his answer concurrently with the sending of his message.

Probably nowhere has the use of the telephone become more widespread than in many of the farming communities of the Western States of America, and nowhere has it worked greater changes than in the social life of such communities. It has virtually removed the sense of isolation that so often wears upon the dwellers on farms. However remote one farm house may be from its neighbours, with a telephone within reach at will, the feeling of aloneness disappears.

In addition to the ordinary uses of the telephone in these communities it is also in numerous ways made to add to their pleasure and instruction. Thus quite frequently tele-



A SPECIAL TELEPHONE TRANSMITTER IS USED FOR CHURCH SERVICE, IMMEDIATELY IN FRONT OF THE PULPIT

phone musicales are arranged at which the musical talent of the neighbourhood furnish the entertainment, while the audience is made up of the subscribers and their friends, scattered over a large territory, the result, it is said, being much more satisfactory than a phonograph entertainment.

A rural news service is also supplied on certain of these farm lines. At a certain hour of the evening, say seven o'clock, a general call is rung over the lines. When all the subscribers are gathered on the lines the central office begins by giving

the exact time of day. The weather indications are then given, together with the latest news of the day from home and abroad, briefly, of course. Then follows the market quotations of farm produce, oats, wheat, eggs, etc.; all of which, as intimated, is working a revolution in rural life.

Ap[ro]pos of these uses of the telephone in American farming districts, it may be noted, by way of contrast, that in Great Britain the use of the telephone is very restricted in the rural districts. An experiment was recently conducted by the British postal-telegraph au-

thorities to ascertain how far it may be possible to make village post offices serve the additional purpose of public telephone call stations. For this purpose six villages have been chosen, and the post offices therein will be set apart as public telephone stations from which any one, by the payment of the usual rate of six pence, may call up any subscriber.

These, however, are instances of the more or less common uses of the telephone in business and social life. Its use in ways that are not so common is becoming increasingly frequent.

For example, one of the most important of the somewhat unusual

An enterprising school teacher was quick to perceive the utility of the telephone in a case of this kind. Some of his pupils were quarantined in their home for two weeks on account of the existence of small pox in the family. Two of the sons were desirous of graduating, and to miss school for this time would have made their examinations and standing doubtful. In this exigency the teacher assigned the regular lessons to his pupils, which he heard them recite over the telephone in the evening, thus enabling the pupils to keep up with their studies and pass their examinations successfully.

In quite a number of instances a



TELEPHONE OUTFIT USED BY THE MANCHESTER, ENGLAND, FIRE BRIGADE

uses of the telephone is that in which it enables those ill with contagious diseases in hospitals to communicate directly and without danger with their friends, which communication obviously would otherwise be impracticable.

modification of the telephone is now used in churches to enable deaf persons and those at the rear end of the auditorium to hear the sermon without difficulty. The telephone has also been used to enable an invalid mother to hear the marriage service



PORTABLE TELEPHONES IN RESTAURANT SERVICE

at her daughter's wedding in a distant city. In other cases the marriage ceremony has been performed over a telephone circuit, the officiating clergyman being at a distance from the bridal pair. In Philadelphia the telephone is brought into service to transmit the preaching and singing at the Baptist Tabernacle to the Samaritan Hospital. For this purpose a string of six megaphones is placed over the platform, and to these megaphones the telephone transmitters are attached. The patients at the hospital can clearly hear the words of the preacher and the hymns.

Holding baby up to the telephone to let a distant parent hear its crowing is now hardly an uncommon use of the apparatus. More uncommon

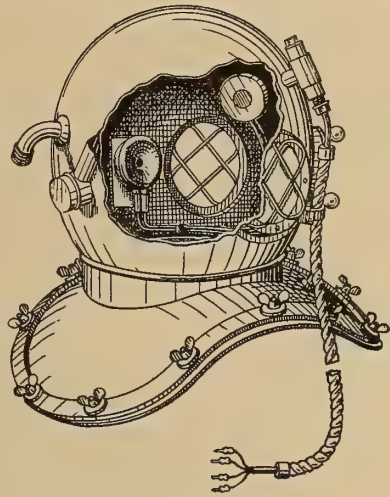
was the somewhat similar use in which the owner of a valuable fox hound that had been lost was called to the telephone and asked to listen to the bark of a dog in a neighbouring village. The hound gave a couple of barks in the telephone which enabled the owner to recognize the animal as his. On another occasion a dog fancier was asked to give his opinion as to the quality of a pup by listening to the bark of the animal in the telephone, the dog being several miles away.

Another recent application of the telephone is its use in recording the hits at target practice. Formerly this work was done by means of flags, different coloured flags indicating a centre, an outer, a bull's-eye, etc. The hits are now verbally

transmitted by telephone, and a marked saving in time results.

The telephone was recently employed on the operatic stage in a rather unique manner, namely, to control and direct the movements of a dragon in the opera of Siegfried at a performance in the Metropolitan Opera House, New York. The dragon, composed of papier-mâché, is moved about the stage in accordance with the music, by two small boys concealed in its interior. The boys are rarely able to do their part accurately, even after laboured rehearsal, but on a recent occasion it was not possible to have a rehearsal. To meet this emergency the stage manager decided to install a telephone circuit in the dragon, and the receivers were strapped on to the boys' ears, whilst their movements were directed from the wings. It is said that with this assistance the dragon comported itself unusually well.

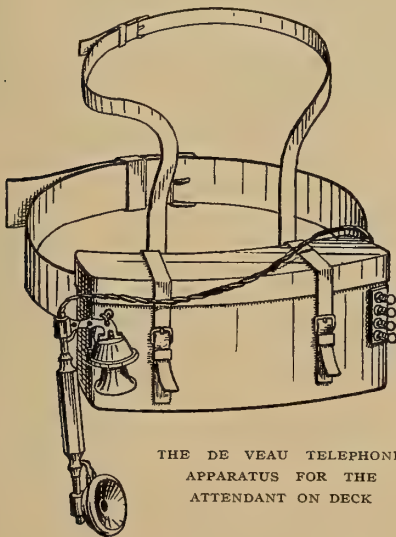
Of a different order to the foregoing described uses of the telephone is the following, in which that instrument is employed to detect wine adulteration. The method, due to Maneuvrier, the well-known chemist, of Paris, is described as follows:—Two glasses, one filled with



A DIVER'S TELEPHONE AS USED BY THE U. S. GOVERNMENT. MADE BY THE DE VEAU TELEPHONE MFG. CO., NEW YORK

the wine to be tested, and the other with a like quantity of wine known to be pure, are placed upon an apparatus resembling a scale, and a telephone is connected with both liquids. If both wines are pure, no sound is heard in the receiver, but if one contains water a noise is produced until a pointer is moved to a given place on the dial plate, whose movements render the conductivity of the liquids uniform. The point on the graded scale of the dial at which the pointer stops indicates the quantity of extraneous matter in the wine. In this instance the telephone is apparently employed in the capacity of a galvanometer.

A German patent has been granted for an application of the telephone principle whereby the presence of a shoal of fish can be detected. This device consists of a sensitive microphone transmitter enclosed in a water-tight case, which is lowered into the water. The transmitter is connected by insulated wires with a telephone receiver and battery on the fishing boat. So long as the microphone hangs free in the water no sounds are heard in the telephone receiver, but when a school



THE DE VEAU TELEPHONE APPARATUS FOR THE ATTENDANT ON DECK



TELEPHONES CONVENIENTLY DISPOSED IN LARGE DEPARTMENT SHOPS

of fish pass, the constant tapping against the microphone case produces sounds which betray the presence of the fish.

The inventor of this device goes so far as to say that, with it, approximately the number and kind of fish in its vicinity can be recognized. Thus, when herrings or smaller fish pass in large numbers they make a whistling noise, whilst the sound made by codfish is more like howling. When very near the submerged instrument the flow of water through their gills makes a noise like the laboured breathing of a quadruped.

The telephone transmitter and receiver are also applied very advantageously in submarine signaling to a distance, in the following manner: A bell at a lighthouse is submerged in the water to a depth of 8 or 10 feet. By means of suitable apparatus the bell is sounded at certain in-

tervals, setting up vibrations which are transmitted through the water. A telephone transmitter is placed in connection with a diaphragm on a cup-shaped vessel filled with a liquid and attached to the hull of a ship. A circuit leads from the telephone transmitter to the receiver in the chart-room of the ship. The sound vibrations in the water set up by the bell are taken up by the transmitter and are heard in the receiver. By having a transmitter at each side of the vessel, it is possible to detect the direction from which the sound has come, and in this way the captain of the vessel is apprised of his approach to a lightship or the shore.

Another important novel use of the telephone is that in which it is employed as a means of communication between submarine divers and the attendants on the decks of the accompanying boats. The illustrations on

page 279 indicate the manner in which the apparatus is connected in the interior of the diver's head-gear. Telephonic communication is maintained by means of insulated wires contained in a cable. This device has been used somewhat extensively by the United States Government.

Firemen are now also able to communicate from the interior of a

tion and for an electric light service. The coupling for the air hose is at the back of the head, and the air is distributed around the head, keeping the eyes and nose free of smoke. The illustration on page 277 shows this arrangement as used at Manchester, England.

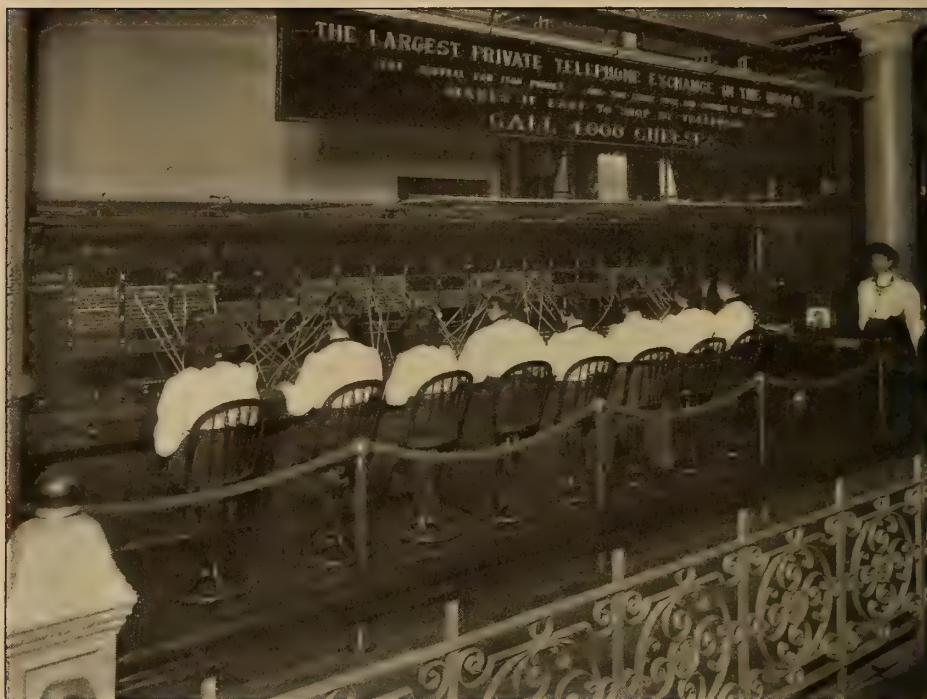
Still another odd use of the telephone is that in which it was employed to facilitate painting the in-



TELEPHONE SERVICE ON THE NEW YORK CENTRAL RAILROAD COMPANY'S 18-HOUR CHICAGO TRAIN. THIS TELEPHONE IS CONNECTED BY PLUG AND JACK ARRANGEMENT TO THE GENERAL SYSTEM AND CAN BE USED UP TO THE TIME THE TRAIN LEAVES

burning building with their officers by means of a telephone outfit contained within a leather helmet. The helmet is provided with a mask that extends over the fireman's shoulders, the front of the mask under the peak of the helmet being left open. The fireman entering the building, carries with him air tubes and wires for maintaining telephonic communica-

tion and for an electric light service. A raft was constructed to float upon the water within the pipe, and served as a platform upon which the men worked. A telephone installed within the water pipe communicated with the pumping room of the water plant. As the painting progressed, the men within the pipe telephoned the engineer at the pump



AN AMERICAN DEPARTMENT STORE "CENTRAL" FOR 1500 TELEPHONES. MAKES IT EASY TO SHOP BY TELEPHONE

house to raise or lower the water in the pipe as desired. By this use of the telephone much time was saved, and the utilization of the raft saved the cost of erecting staging.

Notwithstanding all the important uses, common and uncommon, to which this invaluable apparatus has been put, the world does not yet seem to be unanimous in its opinion

as to its merits. For example, not long ago the national conference of the Old German Baptists, at Flora, Ind., adopted a resolution in which all the members of the church were ordered to discontinue the use of telephones, on the ground that the instrument was a device of Satan, that it makes people lazy, and that there is no warrant for it in Scripture.

PROGRESS ON THE PANAMA CANAL

By Fullerton L. Waldo

IT was the writer's privilege to be associated with a party of eleven Congressmen who, on their own initiative, spent the Christmas recess of 1906-7 in a visit to the canal zone. The party arrived at Colon at nine o'clock on Friday morning, December 28, and left Colon the following Wednesday at 6 P. M., giving us about five and a half days to investigate and ask questions, and see for ourselves what has been done and what yet remains to do. As our boat, the "Alliança," picked her way across the shallow green waters of the open roadstead that serves Colon for a harbour, we were surprised to see two other vessels of the line tied up at the Panama Railroad & Steamship Company's wharves. The "Panama" (of 5700 tons), which had left New York four days ahead of us, had lost those four days waiting for a chance to dock. Immediately after anchoring in the roadstead a norther had forced her to put to sea again with all her passengers and freight, and she had spent the time until the morning of our arrival in the safe harbour of Porto Bello, some twenty-five miles distant. The "Advance" (of 2700 tons), which should have left for New York several days before, was similarly held up in her departure by the storm. This illustrates what happens to vessels which have the misfortune to arrive at Colon in bad weather, and demonstrates the need of breakwaters to enclose the open roadstead and give Colon a protected and commodious harbour. The zone lost its Christmas turkeys this year, which were all on board the "Panama"; but the people of the Isthmus have evidently learned to endure with a cheerful

philosophy their major and minor disappointments and inconveniences, for the absence of grumbling, "kicking," and "hard-luck stories" was quite the contrary of what the muck-rake writers had given us to expect. The President's visit, I was many times told on the Isthmus has done a great deal to dispose of the type known as the "knocker." Cheerfulness and optimism are everywhere in evidence. There is now the feeling that nothing can prevent the consummation of the work. The jack-of-all-trades is disappearing, and the trained specialist is taking his place. The man who arrived on one steamer and without undoing his kit of tools departed on the next boat, is a type that is giving place to the man who brings his family and intends to stay and see the thing through.

The paving of the city of Colon (with vitrified brick laid in cement) is progressing very satisfactorily. The Commission has finished a handsome brick building for office purposes. Tolerable meals and decent beds for white people may be had at the Washington Hotel,—an old French building fitted up by the I. C. C. for its employees, right at the water's edge, and almost exactly on the water-level. Every other shop (as in the city of Panama) is a grog shop, and the string-pieces of the wharves are infested with the usual crowd of loafers and roustabouts and grinning negroes. After the storm, the day of our arrival was a field-day for the port: there were five large steamers in the roadstead and six at the piers besides our own, and the darkies who toted the passengers' hand-luggage from pier to station reaped a fortune in small change.



THE WASHINGTON HOTEL AT COLON

The architecture of Colon is that of a "boom" town in the Western United States. The houses are small, and of wood, and a fire would wipe out the town in a very few hours. The little shops are dingy, and the dwelling houses of the native population are no better than the two-room seaside cottages that desecrate the New Jersey coast. The total population is about 13,000, as compared with some 25,000 at Panama. The most impressive exhibit at Colon is the new town,—its suburb,—Cristobal (accent on second syllable), built by the Canal Commission, being in every way a model of what a homestead working-village in the tropics ought to be. The French built out the point on which the two De Lesseps houses stand, with the monument of Columbus protecting the Indian maiden. These buildings are now used as canal offices. Behind them are rows of new Commission dwelling houses, set high on posts, and screened, and refreshingly exposed to the sea breeze, which stirs the fronds of the tall cocoanut palms like windmill-

arms. Close at hand, where the Folk River enters the old French canal channel, are the remains of eighty-eight submerged vessels of the French company. A cantilever crane and a coal unloader (both built by the Brown Hoisting Company) stretch their wide arms upon the bank. The coal unloader was (December 31) unloading her fourth vessel, but was still in process of adjustment. It appeared to work with the precision and smoothness of a watch, but, under the terms of the contract, it had to be operated successfully for a certain time before final acceptance. The Commission uses 685 tons of coal daily, all imported from the States, and some mechanical unloading device had become an imperative necessity. The French drydock slip at this point is being enlarged to a width of 310 feet. Six lighters are being assembled (the parts coming from the Baltimore Steel Works). Scattered about on the swampy bank near at hand are old sections of French pipe,—originally intended to be filled with concrete for the con-

struction of a sea-wall. There are also in the neighbourhood perhaps twenty-five shiploads of beautifully machined and tooled castings for the (abandoned) Eiffel locks at Bohio.

We saw 50 miles (5000 tons) of rail and fastenings being unloaded by the Norwegian vessel "Tropic," which got its cargo at Baltimore from the

possible in the flood season to go up the river in a cayucca (native dug-out) as far as Alhajuela, some 15 miles above the proposed site of the Gamboa dam.

The dock at Cristobal has been extended 400 feet since April last and a roof put on. This is where the dance and the reception were held at



THE MESS HALL FOR CANAL EMPLOYEES AT CULEBRA

American Steel Company. In general, at both of the canal termini the foreign vessel in the carrying trade is very much in evidence. We noted that at present two French dredges are in use on the Atlantic side and three on the Pacific side of the Isthmus; no American dredges have been employed as yet. It is possible to go up the channel of the canal, as excavated by the French company, about $1\frac{1}{2}$ miles in a tug; then a naphtha launch ascends some 9 miles further; but when the Chagres is in flood the launch can make little or no headway against the current. It is

the time of the President's visit, and where he made his memorable speech to the assembled American engineers and operatives and their families,—a speech that thrilled everyone who heard it. "It made me proud and glad that I was an American," said one of the men who was there to me. "And you ought to have seen the crowd: the way they cheered and shouted and threw their hats in the air defies description: it was a wonderful demonstration of enthusiasm and loyalty to the President and to the work." The roofing of this dock is of corrugated iron (virtually

steel)—inferior to the French iron, which was more thoroughly galvanized.

A large cold-storage plant is being erected, and a bakery had started in the day before our visit. We saw it in full blast, turning out thousands of loaves of light and appetizing bread. It is to have a capacity of 24,000 loaves in a 10-hour day. The loaves weigh a pound and sell for five cents. The kneaders are from the Thompson Machine Company, of Belleville, N. J., and the Duchess Tool Company. Fowler & Rockwell, of New York, make the mixers. The bread requires half an hour to bake in cylinder ovens. It is hoped to increase the output, later, to 30,000 loaves per day. The bakery sends bread to all parts of the zone, thus ensuring a plentiful supply of an all-important article of food. By the middle of January, we were told, the laundry would be in operation, with a capacity of 10,000 pieces a week. Then householders will no longer be at the mercy of the native washerwomen, with their famine-price tariff of \$3 per dozen. The greatest need is, perhaps, for the cold-storage plant and additional ice-plants. The Armour and the Swift companies have sent down men to make recommendations for the storage plant, which will shortly be completed. At present there is a dearth of ice; every pound that is made on the Isthmus finds immediate use. The Panama Railroad has two plants at Colon and one at Panama; but these, and other private plants, cannot produce more than half the needed supply.

The car shops at Cristobal will accommodate 110 cars. This spot, and indeed the entire terminal yard, has been filled in to 4 feet above sea-level. Formerly it was a wreck-filled morass. The very complete equipment of the machine shop is from the Pond Machine Tool Company and the Niles Company. The value of this plant in the United States would be about \$85,000; the total

cost at Cristobal was not more than \$91,000. There is also a 20-stall locomotive round-house. We noticed a (Browning Engineering Company, of Cleveland, No. 3) crane with a capacity of 40,000 pounds at 10-foot radius. Perhaps the most interesting device we saw was a new track-thrower, invented by Mr. W. G. Bierd, the general manager of the Panama Railroad,—a swinging boom, with a side-arm for hauling it over, mounted on a flat car, for shifting tracks on dumps. It can throw 200 feet of track 3 feet 4 inches in 29 minutes with seventeen operations of the machine. Among the rest of the mechanical equipment of the yards is a 75-ton Bucyrus wrecking crane. There is a well-constructed cinder pit, and a coal dock of the Great Northern (Hill) type, with 20 per cent. incline.

Just beyond the yards and shops of Cristobal are the two vast connected storehouses of Mount Hope,—the point of distribution of supplies for the entire Isthmus,—under the able management of Mr. W. J. Tubby. Mount Hope is the locality formerly known as Monkey Hill, the site of the famous burying-ground. In the January sunshine, with the palms and red zinnias and other flowers, the slopes of the cemetery hill appeared most attractive. An 80-foot roadway is being built from Colon to Monkey Hill to handle the native funeral excursions and relieve the congestion in the railway yards. The Mount Hope storehouses are situated on the other side of the track from the cemetery. Here we found that, in the first place, the office work was conducted under a thorough-going card-catalogue system, and that every article had its own pigeon-hole in its own section, as in a well-managed hardware store. I could not see that there was unnecessary red tape in the system of classification and distribution, and without some such methodical arrangement, to ascertain the whereabouts of a desired article would be



A STONE CRUSHER AT WORK AT BAS OBISPO

a hopeless task. Three sections of one building are devoted to the old French stores: vises, planes, picks, cog-wheels, files, augurs and bits, chisels, compasses, indicators, and what-not. There are immense quantities of fence material, of roofing, tiling and lead and wrought-iron piping. Furniture and hotel supplies (e. g., 10,000 tumblers) take up a lot of room, and there are rat-proof cupboards for hotel linen. The two buildings, joined, measure 580 feet in length by 160 feet in width, and the external platform adds 200 feet to the length. In the yard are, perhaps, 100 carloads of French bar-iron of excellent quality. Every effort is made to save the old French material from being relegated to the scrap-heap, though every ship to New York carries away a quantity of unserviceable material. French bolts can be utilized, but not rivets. The old chains and wire cables can no longer be trusted. The flues of the French boilers are mostly played out.

It is indeed a melancholy sight, all along the Isthmus, to see the vast amount of highly specialized French machinery given over to the morning-glory and the bejucca vine and the chocolate-coloured corroding waters of the tropic streams. At Empire fifty or sixty Belgian locomotives are lined up on side-tracks awaiting conversion or deportation. But everywhere the "old stuff" is spoken of with respect as having been beautifully made, of superior materials. I was often told that the French equipment has been of incalculable assistance to our American engineers, and that the price paid for it represented a great bargain. The little French dump-cars, to be sure, look like toys beside our Western and flat (extension) cars, besides being built to dump only on one side, and the small Belgian locomotives are not suited to any kind of heavy work. But the men on the Isthmus never make fun, as we do in the States, of the work accom-



A STEAM SHOVEL WORKING ON THE SIDE OF THE CULEBRA CUT

plished and the tools employed by the De Lesseps company. The vast excavation at Culebra is standing evidence of the gigantic achievements of our precursors on the Isthmus.

At Gatun,—about 10 kilometres (6 miles) from the Colon end of the canal,—we could stand on a high hill by the railroad (where one end of the dam is to be) and survey the entire field of operations. At our feet lay the native village of Gatun, with its shacks and little grey Catholic church, on the point of land where the French canal (27 feet

comparison, that the San Leandro and Pilarcitos dams, in California, are similar earth dams on earth foundations, built by hydraulic methods, the first being 120 feet high and the second 95 feet.

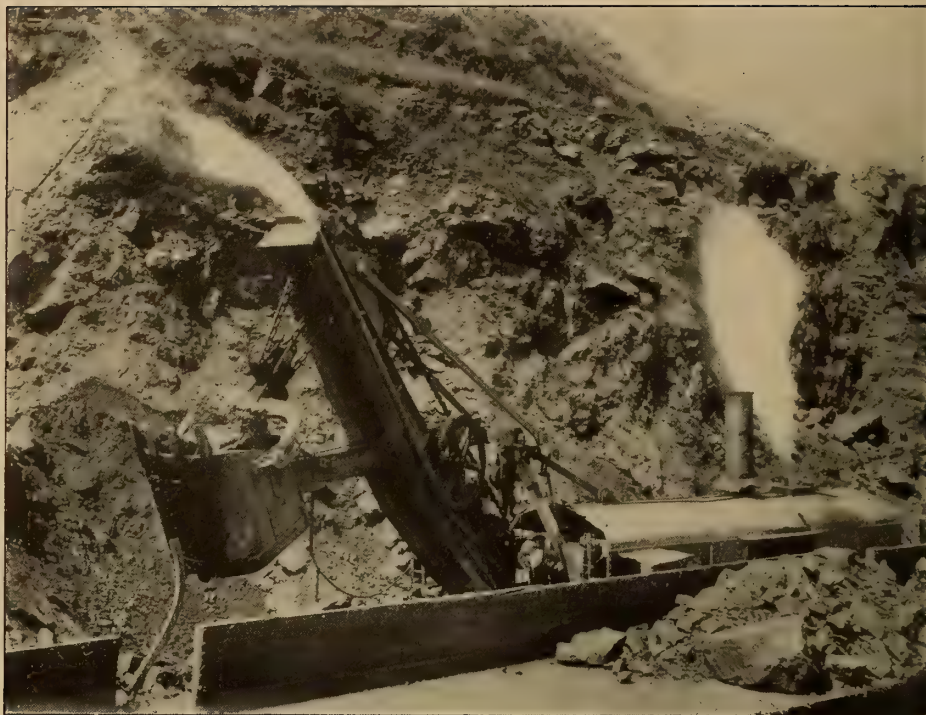
The work of excavation for the locks has been begun, using two 70-ton Bucyrus shovels (of the sixty-three shovels, all of the Bucyrus type, at work upon the Isthmus). The 70-ton shovel is found to be the type best adapted to work here in the soft material (40, 70 and 95 are the three sizes generally used). The entire



BIG BLAST ON CONTRACTORS' HILL

deep) meets the Chagres. This village, of perhaps a hundred huts, will be entirely occupied by the dam site. The dam, 7900 feet across to a point we could clearly see on the hill confronting us across the valley, is to be 3100 feet thick at the base (lower toe to upper toe), and about 370 feet wide at the crest. The top of the dam, 135 feet above sea-level, is 50 feet above the 85-foot lock level of the water of the canal. The dam will contain 22,000,000 cubic yards of earth (perhaps 30,000,000 tons). It may be noted, for purposes of

lock-site area, for the three sets of locks, is not more than 5000 feet in length. It will be from a year to a year and six months before the masonry work (in reinforced concrete) is started. The earth on which the bulk of the dam will rest is said to be impervious. They will not dig down below the surface to provide any other foundation, unless at a particular point it shall be absolutely necessary. The material in which the excavation for the locks is at present going forward is indurated clay,—not quite so hard as slate, and grey



A BUCYRUS STEAM SHOVEL AT WORK IN BAS OBISPO CUT

or slate-blue in colour. The material for the dam will be mainly earth. Every 200 feet square over the entire field borings have been taken, making some 500 borings in all (not four merely, as one critic of the Gatun dam has stated). Perhaps 200 of these borings have been taken on the actual lock site.

The locomotives used at Gatun are 72-ton,—as heavy as it is practicable to use with the soft earth and steep grades. The difficulty of hauling supplies to the quarters of the labourers (on a hill back of the lock-site) has been met by the construction of a wide plank road, which conforms to the curves of the hill so as to secure as gradual a slope as possible.

At Gorgona are situated the principal machine shops, on the line of the railroad. It was necessary to fill in the bed of the Chagres 25 feet at this point to secure a foundation. In

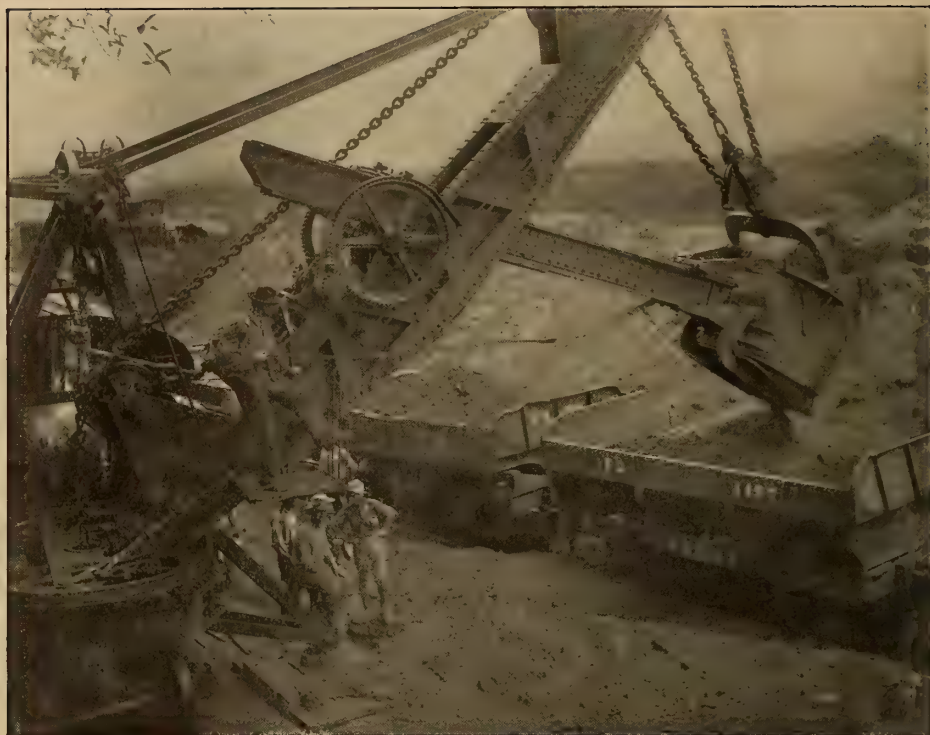
a completely equipped and up-to-date foundry they are working up the old French cast iron into available forms. Most of the new tools are made by the Niles-Bement-Pond Company. Among them we noticed pneumatic riveters, a planer with 24-foot bed for locomotive frames, a Chambersburg steam hammer working up old locomotive axles, portable hoists from the Franklin Portable Crane & Hoist Company, various sorts of lathes and a Betts cold-saw cutting rails into lengths. The Belgian locomotives employed by the French company were being put into commission for light work around the dumps, and car axles were being worked up by drop-forging. In the tool room all tools are made to standard gauge before reissuing, thus insuring standard sizes, just as in our machine-shop practice in the United States. In the foundry the first-class men,—pattern-makers, or whatever they

are,—get 75 cents per hour, gold. No sooner had this department been opened than 150 carloads of scrap-iron were sent in to work up into usable forms. The total effective force at Gorgona is 800-1000 men. It struck me that here in these light, clean and airy buildings American foundrymen and machinists would certainly find little cause for complaint. In the wash-room, with its 210 basins, each white man finds hot water ready when the noon whistle blows. The sanitary closets are automatically flushed every 30 minutes. An advantage of these shops in the tropics is their freedom from smoke and grime, owing to their being open or slatted on all sides. The average temperature of the warmest month (July) on the Isthmus is 76, of the coolest (January) 74. But it must be borne in mind that to produce this average the nights are cool, while the days are hot, and that the excessive humidity of the rainy season (April to December) is productive of much discomfort. During the five days we were on the Isthmus it did not rain once, and I saw but one mosquito and heard two others. The experience of the President's party was that but one mosquito was seen. I did not hear much complaint about the climate, for while the days, especially at noon, were hot, averaging 86 degrees, my attention was called to the fact that there was a refreshing lowering of the temperature at nightfall, usually accompanied by a breeze from the sea. At Culebra through the chief engineer's office the strong trade-wind is usually blowing in the dry season, so that weights have to be placed on the letters and papers. The abolition of the mosquito along the canal route is due to the magnificent work of Dr. Gorgas and his associates. Of course, surveying parties in the woods and swamps still suffer cruelly from insect pests and endure the martyrdom of "unheralded heroes."

At Gorgona, in addition to the

specialized machinery I have mentioned, a dozen Lidgerwood unloaders are being put in commission for plowing the spoil from the vestibuled flat-car dirt trains. A feature is the transfer table, to connect the tracks in front of the machine shops. The one thing lacking to bring these shops fully abreast of the most modern engineering practice is the electrical equipment which will come with the advent of water-power.

We visited the heavy rock cutting at Bas Obispo to witness the performance of the two 95-ton Bucyrus shovels, Nos. 227 and 229. (The 70-ton shovels, with 3-yard bucket, are numbered 100 to 200; the 95-ton, with 5-yard bucket, are numbered 200 and up.) After the rock has been sufficiently "shot" with dynamite, No. 227 rushes at it like an angry bull with head lowered. The white steam shoots from the pipe on the crane, the black smoke regurgitates from the funnel, and when Macdonald, the engineer, throws open the stopcocks of the cylinders the damp soot falls in indelible polka-dots on the new Panama hat and Chinese crêpe shirt of the enthusiastic Congressman who has ventured a little too near. The great shovel seems endowed with an almost human intelligence. If it has taken too large a mouthful of the basaltic trap rock to pass through the bucket door when the latch is pulled, the crane is lowered and the rock is thrown to one side in a muddy pool. Or if the rock has been put on the Western car with its centre of gravity too far over to one side, making the car topheavy, back comes the bucket with its steel teeth, coaxing and shoving the rock into place like an elephant piling teak. When one considers the skill and the judgment required on the part of the shovel engineer and the craneman who pulls the latch, one realizes that \$210 per month for the former and \$185 for the latter is not an excessive salary. These men receive the highest wages of any in the mechanical department. I climbed up on the crane of



IN THE CULEBRA CUT. A 95-TON BUCYRUS STEAM SHOVEL WITH 5-YARD BUCKET

229 to witness its operation at close range. The celerity and smoothness with which these monsters devour the piles of hard, close-textured rock are remarkable. As the President said in his speech at Colon, the steam-shovel man is the man who sets the pace for the rest to live up to.

The stone crusher at Bas Obispo has a record of 620 cubic yards per day. The average daily output is between 350 and 400 yards. The dump cars used for hauling the ballast are of the Ingoldsby and Goodwin types. It was impossible to witness the activity here at Bas Obispo and at Culebra without feeling that no natural obstacle can defeat a body of skilled engineers and mechanics armed with such formidable excavating tools, under the direction of a man like John F. Stevens.

At Culebra,—the crux of the work, quantitatively considered,—we have not yet gone, in a vertical direction,

beyond the lowest point reached by the French, but we have done a lot of cutting at the sides. Gold Hill (on the left of the cut as one faces toward Panama) is 660 feet in height; the top of the hill on the left is 450 feet above sea-level. The saddle between, where the French began to dig, was about 325 feet. The village of Culebra itself is 360 feet. The French have excavated an amount which leaves us with a distance varying from 90 to 130 feet to go in order to reach the bottom of a canal 40 feet deep with its upper surface at the 85-foot lock level. This digging must be done through hard basaltic trap-rock, of the kind macadamized roads are made of in the United States,—similar to our railroad ballast. On the sides of the Culebra cut are what look like patches of red clay or sandstone, but, on closer investigation, there are seen to be places where the basaltic

rock is stained with iron. The summit water-shed, near the heart of the cut, allows water to flow into both oceans.

In the Culebra cut (which extends from Bas Obispo to Pedro Miguel) probably twenty-eight steam shovels are working, on and off. These vary in size from 50-ton shovels used only in light grading work up to the 95-

characteristic sight is that of one laden train waiting at the heels of another train which is in process of loading. Each shovel has from three to five trains to serve it. It takes 30 minutes, on the average, to load a train of ten Western cars, allowing seven 3-yard dippers per car. I saw one car loaded in a minute and a quarter when an extra effort was be-



A PORTION OF THE RAILWAY YARD AT LAS CASCADAS. THE CLEARING HOUSE FOR CULEBRA SPOIL ON THE ATLANTIC SIDE OF THE ISTHMUS

ton Bucyrus titans. The Belgian locomotives are efficient for their own small dump cars, but are not able to handle the Western cars. The performance of the steam shovels is largely conditioned upon the time it takes to haul the spoil to the dumps; if a fresh train of empty cars could be provided the instant one train of Western cars has been sent away loaded to the dump, so that the shovels need not stand idle between times, the work would be vastly accelerated. It is not safe to build a double track on a shelf, and so a

ing made to get out of the way of a dirt train just behind.

The three or four upper shelves of the Culebra cut were dug by the French to keep the dirt from sliding down. In the wet season several steam shovels are frequently run in on the higher levels,—like mountain howitzers, as President Roosevelt has said,—to dig a bench and prevent a slide. It can be seen that the determination of the psychological moment to send in these field-pieces is a nice problem of engineering judgment.



IN THE CULEBRA CUT, NOVEMBER 16, 1906. LOOKING NORTH TOWARD COLON

We watched a churn-drill working at the brink of the cut. In six days a 90-foot hole (100 yards back from the face of the cut) can be drilled. In and around the cut the decaying French machinery is much in evidence. On the Panama side, just before reaching the heart of the cut, is a line of perhaps twenty-five dump-cars covered with morning-glory vines, and a lot of trucks lying in rusty rain pools. There are French excavators, keeled over on their sides, with revolving chains of buckets similar to those on bucket-dredges. The contrast between these excavators and the mighty American 70-ton and 95-ton shovels marks the great advance of the last twenty years in mechanical engineering. The old French buildings have been utilized extensively by the Commission in housing the employees at Culebra, but are now being rapidly supplanted by new houses of better construction, care-

fully screened. By the first of February the last of the French dwelling houses will have been razed. In the new Commission hotel we ate a very good dinner, which costs an employee thirty cents and an outsider fifty. The bill-of-fare was: vegetable soup, steak, with baked potatoes and rice, corned beef hash, stewed corn, apple pie, coffee and iced tea. The young men sitting around me looked like the average group in a college dining-hall in the United States. They did not look, by any means, unhealthy, but a perceptible pallor had in many places taken the place of the ruddy glow of perfect health one might have found in the North. On the whole, from one end of the zone to the other, the men looked pretty well, and they generally confessed to feeling well, except for occasional touches of malaria. (The most prevalent serious disease on the Isthmus at present

is rather singularly, pneumonia. The ablest men were usually the most healthy-looking; you did not find them tipping,—they obeyed to the letter the stringent laws laid down by Nature for the existence of white men in a tropical climate.

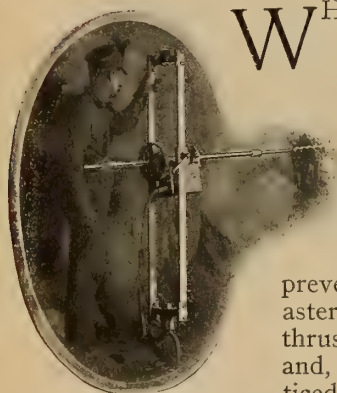
The Pacific terminus of the canal, La Boca, is the only place where large boats can dock. The Panama Railroad has wharves at Panama, three miles distant; but these are available only for lighters and small vessels. At the first La Boca wharf (perhaps 500 feet long) a coaling station is being built with a Bucyrus pile-driver. The creosoted piles only survive the ravages of the teredo worm for about three years. They were expected to hold out for twelve or fifteen years. The timber used is mostly yellow pine, with some cypress. The natural timber would last one and one-half or two years, so that it can be seen that it hardly pays to apply the creosote. But for the popular insistence on "getting something done," which has all along been a hindrance to the canal work, these piles would have been permanent affairs of concrete or iron, and would not have required renewal. A second wharf extends the first several hundred feet further. Here ships are

unloaded by means of four Wellman-Seaver electric cranes, with a capacity of 3500 lbs. apiece. Several boats from various South American points were discharging their cargoes or taking on cargoes and passengers for San Francisco and intermediate points (a 22-days' journey). We spent some time examining the site of the two locks (in duplicate), which will effect the descent of 55 feet, to mean tide, from the lake level. The maximum tide at La Boca is 20 to 24 feet, the average is 17 feet. The Pacific terminus of the canal will always require dredging, up to the locks. The water of the harbour is, nine-tenths of the time, of the unruffled smoothness characteristic of the Pacific, and ships in approaching the Pacific end need anticipate none of the difficulties experienced occasionally by ships caught in a "norther" at Colon. The canal ends in deep water about 3 kilometres (nearly 2 miles) off shore, opposite a picturesque group of three or four hilly islands. The decrease in rainfall between Colon and these islands is remarkable. At Colon the rainfall is 160 inches annually, at Panama 75, and at Taboga Island, where the sanitarium of the Commission is located, it is only 30 inches.

CAUSES AND PREVENTION OF DISASTERS IN MINES

By G. Farmer, M. I. M. E.

Among the various causes of disasters in collieries, those having their origin in the explosion of firedamp or of finely divided coal dust are undoubtedly the most important. Many devices have been proposed to minimize the danger from these sources, but it is generally realized that coal mining is necessarily a dangerous occupation, and that the real road to the reduction of the danger element lies mainly in the application of broad scientific principles to the methods employed, rather than in the equipment of a colliery with any specified device. The relations between variations in atmospheric pressure and the emission of gases from the subterranean strata is an example of one method of warning only practicable by continual observation and record. Mr. Farmer discusses the subject in the light of his large experience as a certified colliery manager, and among other occurrences he takes into account the disaster at Courrières, in France, besides considering mining conditions in Great Britain.—The Editor.



WHEN such a disaster as the recent explosion at Courrières mine occurs public sympathy is so aroused that an endless number of appliances for the prevention of such disasters are speedily thrust on the market, and, as has been noticed on this occasion in view of such an accident recurring, provision has been promptly brought before the notice of mining engineers for meeting the great emergencies in the most prompt and effective manner by appliances which have been, and are, found to be effective more or less. The death roll in the mines of the United Kingdom for many years has reached an average of about 1100 per annum, but it is generally found that it is only when a disaster of great magnitude occurs that public sympathy to any great extent is aroused. Accidents resulting in a single fatality are simply looked upon as passing events, and only that in a local sense, whilst many such fatalities are preventable if more care is used and a stricter observance and adherence is given to the Coal Mines Regulation Acts.

Such disasters as have from time to time wrecked hundreds of homes and burdened the public with scores of widows and orphans inevitably call for the ingenuity of mining engineers in devising some means for their prevention. Happily, some such means have been devised, and a marked reduction in the number of disasters has been the reward. This has, to a great extent, been the outcome of such institutions as the North of England Institute of Mining Engineers, which have combined with other similar institutions to form a Federated Institute of Mining Engineers. The North of England Institute of Mining Engineers was formed as far back as 1855, and it then took up the work to try to reduce the number of accidents, and better the conditions of the miner. The work succeeded, so much so that the present conditions underground, in the words of an old miner, "are a perfect paradise," as compared with the conditions in days gone by, whilst the number of accidents have been brought down to one-fourth of what they were at the formation of the institution.

The most dreaded and the most disastrous of all accidents to which the miners are subjected is that of explosion of firedamp and air, which, however, is sometimes aggravated and extended by the addition of coal

dust. Explosions in coal mines have formed the considerations of several Royal Commissions, but, despite their labours, in spite of our rapid advance in the science of mining, in spite of the vast improvement in colliery management and more stringent legislation, colliery explosions continue to occur from time to time, as they have done since the early days of mining, although fortunately not so often. They can be traced as having occurred in the British Isles as far back as the middle of the seventeenth century. In 1850 government inspectors were appointed, and in 1851 mining records were first kept. Since that time statistics and reports have been carefully prepared by inspectors appointed for the purpose.

Before dealing with the conditions under which explosions occur, it may be interesting to mention an explosion which occurred in 1708 at Fatfield, which resulted in the death of sixty-nine persons. The following quaint account of the disaster is given in the "Transactions of the Royal Society of London," by the Rev. Dr. Arthur Charlett, concerning a colliery that was blown up near Newcastle:—

"On Wednesday, the 18th day of August, 1708, at Fatfield, in the parish of Chester-le-Street, about 3 o'clock in the morning, by the sudden eruption of a violent fire which discharged itself at the mouths of three pits with as great a noise as the firing of a cannon, or the loudest claps of thunder, 69 persons were destroyed in an instant. Three of them, viz., 2 men and a woman, were blown quite up from the bottom of the shaft, 57 fathoms deep, into the air, to a considerable distance from the mouth of the pit, one of the men with his head almost off, and the woman with her bowels hanging about her heels. The machine by which the coals were drawn up, and it is of a great weight, was blown off by the force of the blast, and what is more wonderful, the fish which were in the rivulet that runs 20 yards un-

der the level, and at as great a distance from the mouth of one of the pits, were in great numbers taken up dead, floating on the water, by several of the inhabitants."

Such an account gives a lucid description of the force of an explosion. The most disastrous ever recorded in Great Britain was that at the Oaks colliery, near Barnsley, Yorkshire, on the 12th of December, 1866, when 334 men and boys were killed, which was followed by other explosions on the next day, when 27 explorers were killed, thus making a total of 361. On the same day as the latter, the 13th, another explosion occurred at Talk-o-th-Hill colliery, in Staffordshire, at which 91 men were killed.

According to government statistics, the great army of men and boys killed by explosions at collieries from 1851 to 1890, inclusive, numbered 9055, an average of 226.37 per year.

In the year 1891, one of the most favourable years since accurate statistics were compiled, only 51 deaths were caused by 23 separate explosions. In the year 1892 12 separate explosions killed 123 persons. The largest number of deaths occurred in 1866, when 73 explosions caused the loss of 654 lives.

The smallest number of deaths occurred in 1903, when only 14 persons were killed by explosions.

The following table shows the number of deaths due to explosions since 1851:—

Decade of Years, Inclusive	Total Number of Deaths Due to Explosions	Average Per Year
1851-1860.....	2,441	244.10
1861-1870.....	2,270	227.00
1871-1880.....	2,686	268.60
1881-1890.....	1,661	166.10
1891-1900.....	1,024	102.40
1901-1905.....	402	80.40
	10,484	190.60

The above table shows a decided fall in the number of deaths since 1880, and a consequent fall in the average per year; but this table is more striking when compared with the very great increase in the number of persons employed, of which

the following table gives particulars:—

Year	Persons Employed at Mines	Number of Persons Employed to Each Death from Explo- sions for the Year
1851.....	216,217	673
1861.....	282,473	2,374
1871.....	370,881	1,378
1881.....	495,477	4,271
1891.....	667,983	13,098
1901.....	806,735	6,454
1902.....	824,791	13,092
1903.....	842,066	60,147
1904.....	847,553	38,525
1905.....	858,373	4,822

It is evident that for many years colliery explosions have been the subject of the most anxious thought and investigation. If it had been an easy one to deal with, explosions would be things of the past; but in spite of all legislative and other precautions, they are still frequently with us, as will be seen from the fluctuating ratio of persons employed to each death, and demand for their prevention the sleepless vigilance of all concerned.

Firedamp, as is well known, is a gas disengaged in coal measures. Its properties are very similar to methane, or marsh gas, of which it contains about 70 to 85 per cent. A mixture of firedamp with 30 to 15 volumes of air burns rapidly in immediate contact with flame, which elongates, widens, and appears to be surrounded with a blue halo. It diminishes in intensity in proportion to the diminution of firedamp, and disappears when mixed with more than 30 volumes of air. When mixed with 14 times its volume, the mixture is at once converted into flame of little explosive force. From 14 to 8 volumes the flaming becomes quicker, and the explosions louder, until the proportion of 9.52 of air to 1 of firedamp is reached, when the mixture is most explosive. From this point, as the volume of air is decreased, the explosions become less intense, and cease when the proportion is 4 to 1. The mixture still ignites if composed of equal volumes, and when the air is further diminished the flame is extinguished from deficiency of oxygen. The formation of firedamp cannot be

controlled, since it is naturally given off from the composition of the coal. Its presence may be diminished by an ample and adequate ventilation, but the best preventive of disaster from this cause lies in the removal of means by which the mixture can be ignited.

Rate of Explosion.—When explosion occurs the chemical change is propagated through the gas in the form of the "Explosive Wave." The rate at which the change travels depends upon the manner of ignition and upon the percentage of gas present. The velocity of the wave gradually increases for a short time when a maximum is reached which is constant; then it assumes a vibratory motion, and eventually either dies away quietly or terminates quickly with a loud report. This is one reason why miners generally say there is always, or nearly always, an "after-clap."

The phenomena accompanying colliery explosion are:—

(1.) Large Volume of Flame, due to burning of the Gases.—This depends to a great extent on the composition of the mixture, as the presence of nitrogen and carbonic acid gas tends to increase the flame.

(2.) Great Expansion of Gases.—This is chiefly due to the expansion of the products of combustion caused by the high temperature developed, and not to any increase in the volume of gases produced by the change when marsh gas burns to carbon dioxide. The volume of steam and carbon dioxide together is the same as that of the marsh gas and oxygen, if measured at the same temperature and pressure, but when carbon monoxide (CO) is formed 2.5 volumes of firedamp and oxygen give 3 volumes of steam and carbon monoxide, an increase of 20 per cent., which is not sufficient to account for the considerable expansion that takes place.

(3.) Contraction of Gases, Accompanied by Inrush of Air.—This is due to contraction, owing to cooling

of heated gases and condensation of steam to water.

When an explosion of firedamp occurs a very high temperature is immediately generated, and although we can only conjecture what happens in the mine afterwards, it is probable that great pressure proceeds in every direction from the seat of origin. This pressure is sufficient to form a block to the incoming air, and the intake airway between the seat of origin and the downcast shaft remains for the moment charged with air whose motion has been checked. If there be little firedamp at the initial seat of origin, and the explosion is not extended by coal dust or by further explosions of firedamp, it will soon exhaust itself without doing much damage. But if the fringe of a large volume of firedamp be ignited, and there are abundant facilities for its becoming rapidly mixed with air, then the explosion is certain to be very serious. Similarly, if from the gradual accumulation of firedamp and its admixture with air, either by diffusion or mechanically, a considerable volume of explosive mixture has been formed, a more violent explosion would be the immediate result, even though a smaller quantity of firedamp might have been exploded. If to either of the above conditions be added dusty roadways in unbroken communication, the resultant explosion would certainly be indefinitely aggravated. Generally, little damage is to be seen at the initial seat, but from 50 to 100 yards away the explosion wave attains its maximum. The violence exerted by an explosion is due, as has been said, to the sudden expansion of the gases and air from the heat of combustion in a more or less confined space. The expansion begins directly the explosion is initiated, but for a brief period it is only sufficient to compress the air in the ramifications of the mine, then possibly to form currents of its own, some of which would travel against their previous direction and finally to find relief at the shafts. Probably

the full-blown flame forming the explosion wave fills the roadway sectionally; it may also be assumed from observations after colossal explosions, if the roadway near the nascent explosion wave contains coal dust of the most inflammable nature, that the maximum strength of the initial explosion will be thereby increased, becoming fiercer, and exerting greater force owing to the ignition of the gases enclosed in the dust and to the expansibility produced by such ignition. If not met with in the earlier course of the wave, coal dust may at a later stage revive into fresh animation the enfeebled flame, and so either extend it gradually or lead to a new explosion. Nearly every explosion is intensified in effect by the newly compressed air immediately preceding the explosion wave blowing down the roof timbers and supports, thus causing the roof to collapse and possibly liberating additional firedamp from above to feed the already furious flame, causing it to burst out into flashes of great vehemence with accelerated flame-speed and increased expansive force. Observation will often show such terrific spurts unmistakably. Survivors will often speak of the direction of the blast being "opposite to the intake," that is, against the air current. It is safe to say, however, that it travels in all available directions from its seat, and that, therefore, it assumes a direction against the air current on one side. Immediately behind such a wave, and at or near the seat of origin, a partial vacuum is created by the expulsion of air, and afterwards, a partial retreat of the wave towards its point of origin. In serious explosions the forward movement is, however, quickly resumed, as in every case the partial vacuum is quickly destroyed. Survivors have often testified to a "push" and a "suction," and also to a temporary reversal of the air current.

Indications of route taken by the explosion wave are often shown by

the coked dust deposits, charred and burnt timbers, tubs or wagons thrown over, timbers knocked down, roof-stone falls, stoppings, ventilation coursing doors and sheets, and air-bridges blown away. These obstacles are often aggravated by long lengths of fallen roadways that take months to restore. It rarely happens that both shafts are damaged, but in most severe cases the down-cast is more or less affected, and frequently hours elapse before it is sufficiently repaired to permit a descent, whilst it is rarely safe to descend the upcast shaft owing to the afterdamp and poisonous gases which may begin to ascend this shaft immediately after the explosion.

To the casual reader, the above may give some indication of the extreme difficulties which have to be overcome in exploring work after the explosion. The delay, often occasioned by compulsory repairs, in many cases brings out the expression, "too late," and eager as explorers are, their hopes of rescue are brought dismally low.

The disaster at Courrières mines, in France, on March 10, 1906, which led to the death of about 1100 miners, is more than of ordinary painfulness, inasmuch that the mines were looked upon as remarkable examples of scientific working. Besides the well-known system of timbering and of supporting the roof with iron and steel bars adopted, special attention was drawn in the Paris Exhibition to another arrangement as of great advantage, in the following words:—"All the shafts are connected with each other by well-kept galleries." Nobody could have imagined that this arrangement, provided with the very best possible intentions, could one day prove itself so terribly fatal by allowing the explosion wave to travel to such an extent as to lead to the wholesale slaughter of the miners who had worked hard in making those galleries. There were no barriers between the shafts to confine or isolate any fire or explosion

that might happen in any one of them. Owing to obstructions, the first descent of explorers could not be made until March 12 between 5 and 6 P. M., about sixty hours after the explosion. Too late! It goes without saying, and, in fact, the details could not be brought within the scope of this article, that the work of the explorers, although supplied with oxygen-breathing appliances, was of the most arduous and terrible nature from the following reasons:—First, their hopeless task of rescue, from the fact of being too late, filled them with despair and agony. Secondly, the mine was so shattered as to make their late efforts slow and cumbersome. Thirdly, the roadways were so filled with irrespirable gases and the air poisoned by the effluvia given off by dead bodies as to render the work impossible without the oxygen-breathing appliances, whilst with these appliances the work was naturally slow and of short duration. Fourthly, the presence of a still burning fire in the pit rendered the mine liable to still further explosions.

Without a doubt, no one can imagine the sufferings pent up in the minds of that noble army of explorers, who certainly carried their lives in their hands with as much uncertainty as an egg in a spoon, whilst the living death endured by the poor, helpless creatures who were live victims to the ravages of the disrespectful blast cannot be at all described even by the most sensitive writer.

What are the causes of such disasters? Even a strict government inquiry, in many cases, only tends to puzzling complications. Owing to difficulties arising from conflicting evidence, or from the interpretation of facts, experts often disagree not only as to the cause, but as to the initial point of origin, and also as to the direction taken by the blast. From searching public inquiries, reports prepared by the government Inspectors of Mines after an explosion.

and from evidence laid before the Royal Commission on Accidents in Mines, together with experiments in specially constructed galleries, the following causes may be enumerated:

The ignition of a mixture of fire-damp and air, or of a mixture of firedamp, coal dust and air, by:—

- (I.) a naked light.
- (II.) a defective safety-lamp.
- (III.) the flame from a shot.
- (IV.) the flame from any burning material.

In the matter of prevention, no naked lights should ever be allowed in our coal mines, not even in those mines which are said to be free from firedamp. A moral in this respect can be drawn from the Courrières disaster, the Courrières mines being thought to be free from firedamp and worked with naked lights. No excuse can be made for taking matches into the mine, for the Coal Mines Acts in England gives the mine managers power to institute searches of the men employed.

The modern safety lamp, which depends for its safety on the scientific fact that flame will not pass through the standard gauze to ignite the outer atmosphere, has been brought to a high degree of perfection. The gaseous atmosphere enters the lamp and burns with a blue halo over the ordinary flame, but if the standard gauze of 784 apertures to the square inch is used it cannot do harm, whilst it is an indicator of the approaching danger of gas to the user of the lamp. The results of the trials at the official testing station at Frameries, in Belgium, show that explosions caused by the ignition of gas from safety lamps may be classed as preventible, if the best modern precautions against opening the lamps are observed, and if modern appliances for relighting extinguished lamps are provided. The writer has known reckless miners who have opened their lamps even in the presence of explosive gases, but this is now impossible with the modern compressed air or magnetic lock. Modern lamps

are also fitted with such apparatus as will extinguish the light even if the miner does succeed in opening a lamp which has not been properly locked. If a lamp becomes defective, it is only when it has either become broken, when it should be at once extinguished, or when it has been improperly fitted together, which condition should be found during the compulsory examination of the lamps.

The flame of a shot was a subject of more consideration when the older forms of gunpowder were used than at the present time, with the modern mining explosives. Many experiments have been made by the North of England Institute of Mining Engineers, and the Royal Commission on Accidents in Mines, at Woolwich Arsenal, on mining explosives, with the result that the home office issues certain rules restricting the use of all explosives under certain conditions, and practically prohibiting the use of gunpowder under every condition. The result of these experiments is that a list of "permitted" explosives for mining purposes has been carefully compiled, only such explosives as have clearly stood certain critical tests being allowed. In these experiments the aim has been to lower the temperature of the ignited explosive below that at which the surrounding mixture of gas and air will ignite. All who are acquainted with mining operations admit the danger of firing shots in fiery mines, especially where coal dust is likely to be present. This danger is more accentuated in the minds of those who believe that coal dust alone is, under some conditions, inflammable. There is the fact standing out prominently, that a large proportion of explosions have been attributed to the practice of shot-firing. In many cases the evidence showed conclusively, from the positions of the bodies of men engaged in shot-firing, that they were at the time of death sheltering themselves from the effects of a shot, or at points they would take in order to

warn others from approaching the zone of the shot. There is the further evidence of the battery in possession of the shot-lighter. Mines have been said to be free from firedamp when the gas would not "show" on the safety lamp, but the modern safety lamp will not "show" less than 2 or 2.5 per cent., whilst in the region of shot-firing, even when precautions are taken to water the dusty roadways, such a quantity would be extremely dangerous. Firedamp indicators have been put in use that will indicate the presence of 0.5 to 2 per cent., but such instruments are not placed in the workmen's hands, therefore he cannot find less than 2 or 2.5 per cent. Professor Galloway and Sir Frederick Abel established the fact that 2 per cent. of firedamp mixed with an atmosphere impregnated with coal dust renders the mixture explosive. Water may be used to lessen the risk from dust, but generally the water does very little good, unless used very copiously, and in the case of a blown-out shot the risk of an explosion is always present.

Why blasting should be resorted to is somewhat of a puzzle, for its abolition altogether will not generally involve any formidable inconvenience, because the work which is accomplished by its employment, both in coal and in stone, can now be performed with equal efficiency and at very little, if any, greater outlay, by one or other of the following available alternative means:—

(a) In some coal seams the lime cartridge will perform work quite equal to that accomplished with powder, at no greater cost, and with absolute immunity from risk of explosions.

(b) Mechanical appliances exist which will do efficient work, not only in some kinds of coal, but also in some stone or shale over or underlying the coal.

The above methods are taken from the report of the Royal Commission on Accidents in Mines, and the writer is personally acquainted with

a colliery where both methods have been used with great success.

One of the most dreaded forms of disaster to contend with in a mine is fire. It is to this category that the terrible disaster at the Courrières mine appears to have been originally due, and which appears to have been a combination of fire and gas explosion. A fire might be originated by a naked flame being applied to some combustible material, by the arc formed from improperly designed electrical machinery, by the close contact of a steam boiler or ventilating furnace underground with the coal seam or oily shale, or by spontaneous combustion, the latter being known as a gob-fire. The usual method in extinguishing such a fire is to isolate it by strong barriers, and thus, by excluding the access of air, to cause the fire to smother itself with its own products of combustion. Observation of disasters from time to time have condemned this practice as dangerous, for gases may be formed by the distillation of the coal, causing the accumulation of an enormously high pressure behind the barriers. The barriers are always liable to burst when the admission of a little air may be sufficient to feed the smouldering fire into flame in contact with the gases. Even if the fire is thought to be actually extinguished behind the barriers, the greatest precautions must be exercised in opening up the enclosed space, since the dissipation of the heat is very slow and the fire is apt to break out again. The only effectual method of extinguishing a fire is to attack it directly and dig it out, for by this method no gases can accumulate, and none can be distilled or formed by distillation by the fire. The writer has had personal supervision of several underground gob-fires, some of which have been of very large dimensions, and in every case they have been dug out without the loss of a single life. The last one practically covered an area of 56 yards by 25 yards, and took nearly three months, without one minute's

cessation, to extinguish. Over 100 men were employed, divided into three shifts of eight hours each, one set of men always working until the coming-on set were actually ready to take up the tools. One can readily see that such operations are extremely dangerous, long and difficult. Water is used to cool down the débris during the act of digging out, this causing large volumes of steam to be readily given off, which has a ruinous tendency to break and split up the adjoining strata. The work is rendered all the more difficult by reason of the high temperature and poisonous products of combustion. Fires may be isolated and flooded, but by doing so the adjoining strata is practically ruined, whilst the moisture retained by the coal and strata, after the water has been pumped out again, is always liable to originate fresh fires.

Many other minor causes of explosions may be enumerated, but which only require rigid discipline and strict compliance with all rules and regulations to prevent.

In order, as far as possible, to prevent explosions, and limit their fatal effects when they do occur, the following may be looked upon as absolutely necessary:—

(1.) Render harmless all issues of firedamp by constant and adequate ventilation, not allowing such gas to be formed except naturally.

(2.) Prevent, as far as possible, coal dust from being blown off the coal trams or carried down from the surface screens by the downcast current of air, and thus reduce the deposition of coal dust on roadways. It is always wise to erect the screens as far away from the downcast shaft as possible, and in the traffic to use good, sound trams, preferably steel.

(3.) Thoroughly dampen and keep in a damp condition all coal dust

which is unavoidably deposited in roadways.

(4.) Rigidly exclude all naked lights, and by periodical searches make it known to workmen the danger of taking matches, etc., into the mine.

(5.) Prohibit all explosives as far as possible. Where explosives are found absolutely necessary, as in sinking staple pits or very heavy stone work, use only such explosives as are on the "permitted" list, and only then in strict accordance with the "Explosives in Coal Mines" order.

(7.) Employ only the best designed and most carefully erected forms of electrical machinery, in compliance with the "Rules for the Installation and use of Electricity in Mines."

(8.) Employ only the most competent men at all work involving risk and responsibility. Before employing officials it is most important that the management should be thoroughly acquainted with the applicant's capabilities, and the applicant should be compelled to show a certificate of competency obtained by examination. The manager is compelled to place his entire trust in the under-officials; they should, therefore, be capable of carrying out all the requirements of the Coal Mines Acts.

(9.) Enforce strict discipline and full compliance with all rules and regulations. Remember that one broken barrier in a fence renders the whole fence useless. Every transgressor should have meted out to him "the punishment to fit the crime." Managers when besought to think of an offender's innocent family, should not fail to think of the equally innocent families of the many men whose lives were put in danger by the offence. The greatest good to the greatest number is a principle that should be applied in all such cases.

THE MAGNETITE ARC LAMP

By J. L. R. Hyden

ARC LIGHTING was first done by the so-called open arcs, that is, lamps in which the air had free access to the carbons. These were extensively used, and are still occasionally seen. Such lamps have the disadvantage that they require frequent trimming and give a light which is rather unsteady, since the arc is exposed to air draughts.

By enclosing the arc in an almost air-tight inner globe, the consumption of carbons was greatly reduced and the steadiness of the light increased, thus giving the long-burning arc lamp, which required trimming only once a week or even less frequently. The enclosed arc, however, gives less light than the open arc, that is, it is less efficient. In spite of this disadvantage, the enclosed arc lamp has largely superseded the open arc.

The incandescent lamp has been improved greatly in efficiency in the last few years, and more efficient ways of using gas for lighting have also been introduced, so that the superiority of the arc lamp became less marked. Therefore, improvements in the efficiency of the arc lamp became necessary if the latter should keep the field against the incandescent lamp and the Welsbach gas light. Very efficient arc lamps have been made using flame carbons, that is, carbons which contain some chemicals, usually calcium compounds. These lamps are very much more efficient, giving several times as much light, for the same power, as the enclosed carbon arc, but they are necessarily short-burning, since they must be open arcs, so that the fumes or smoke which the metal compounds produce can be carried off and rendered unobjectionable.

A serious disadvantage of the flame-carbon lamp is the orange-yellow colour of the light which it gives. This colour may be desirable for decorative effects, or for adver-



FIG. 1.—A MAGNETITE ARC LAMP FITTED WITH SPECIAL CLOSED BASE, OUTER GLOBE AND LARGE ONE-PIECE REFLECTOR, MADE BY THE GENERAL ELECTRIC CO., SCHENECTADY, NEW YORK

tising, but people generally have become used to insist that artificial illumination should approach daylight as near as possible,—that is, whiteness of the light is considered as an essential advantage. The attempts to produce flame carbons which give a more nearly white light have, so far, resulted in a serious decrease of efficiency, and such carbons have, therefore, not come into general use, and probably will not, since, as open arcs, they require daily trimming, and to-day the short-burning or open-arc has been almost entirely replaced by the long-burning lamp.

To produce a long-burning arc lamp which is as efficient as these flame carbon lamps, carbon could not be used at all, but some other material is required which is not attacked by the air. This has been found in magnetite. Magnetite, or the black oxide of iron, Fe_3O_4 , one of the most common iron ores, is a material which is absolutely stable at all temperatures, is conducting, gives an arc of white colour and high brilliancy, and so is suitable for use instead of carbon in arc lamps.

So the magnetite lamp was developed as the result of an extended investigation by Dr. C. P. Steinmetz into the methods of improving the efficiency and character of arc lighting. In this new arc lamp steadiness and white colour of the light are combined with a high efficiency and long life of the electrodes. It was found that the arc flame which carries the current is fed by the negative terminal only. It shoots out from this terminal almost in the form of a blast flame. The positive terminal takes no part in the production of the arc flame, and its material is, therefore, unessential. It is necessary only that the positive does not get so hot as to burn or melt off. To avoid this, the positive is made large and of a metal which is a good conductor of heat, thus carrying away the heat. Still, it must not be too large, otherwise, by running

too cold, a deposit forms on the positive, and the latter increases in size by building up and loses its shape. A certain size of positive gives the best results, running neither too hot nor too cold.

For the negative electrode, magnetite alone can be used. But while giving more light than carbon, for the same power, pure magnetite is not so efficient as some other oxides of metals of the iron group; accordingly, a small percentage of other metallic oxides is added to the magnetite to increase the efficiency. Pure magnetite is consumed rather rapidly. An electrode of pure magnetite does not last any longer than a carbon in an enclosed lamp, and it also tends to unsteadiness or flickering of the light.

The life of a magnetite electrode, 8 inches long and half an inch in diameter, is about 180 to 200 hours; that is, much longer than that of an enclosed arc electrode.

In the magnetite lamp, as shown in Fig. 1, the positive electrode is not consumed at all, and is made of copper as a permanent part of the lamp. Only the negative electrode is a magnetite stick. It consists of a thin iron tube, which is filled with the finely powdered mixture of magnetite and other compounds.

The lamp mechanism is essentially different from that of the carbon-arc lamp; it regulates for a constant arc length. Since the light comes from the arc flame itself, a constant amount of light requires constant arc length. Therefore, the mechanism is so arranged that in starting or when the magnetite stick has burned off and the arc voltage increases, the magnetite stick is brought in contact with the copper positive by the operating magnet pulling the negative electrode up by means of a clutch, and the circuit closed hereby energizes a series coil which short-circuits the operating magnet and so releases the clutch and separates the terminals to their fixed distance, about nine-sixteenths of an inch.

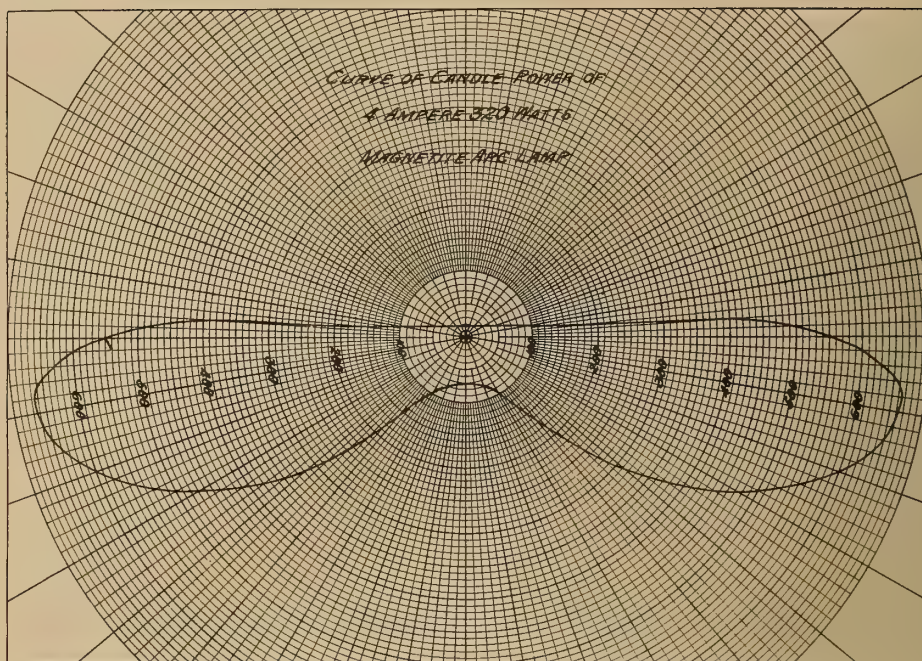


FIG. 3.—CURVE SHOWING DISTRIBUTION OF LIGHT FROM MAGNETITE LAMP

The distribution of light given by the magnetite arc lamp is especially suitable for street illumination.

The intensity is a maximum slightly below the horizontal direction, as shown by the distribution curve, Fig. 3, and only a small amount of light is thrown in the downward direction, so that the lamp gives a far more uniform street illumination than the carbon arc. It does not give the glaring bright spots underneath the lamp, separated by regions of darkness. This is best shown by the two diagrams in Fig. 2. These show two streets,—one illuminated by 480-watt alternating lamps, 240 feet apart, and consuming 2 watts per linear foot of street surface; the other illuminated by 300-watt magnetite lamps, 300 feet apart, and consuming only half as much power, or 1 watt per linear foot of street surface; the height of the light space shows the amount of light each part of the street receives. As shown, the magnetite lamp at half the power consumption of the carbon lamp gives 50 per cent. more

light midway between the lamps, where the street is darkest, and light, therefore, is most wanted, and gives only about half as much glare in the bright spot under and near the lamp. The latter is a great advantage, since the bright glare underneath the carbon lamp tends to blind the eye, and thus makes the dark regions between the lamps appear still darker.

The magnetite lamp is a direct-current lamp, using 75 volts at 4 amperes. It was first operated from Brush machines, redesigned for 4 amperes.

Although the direct-current lamp is more efficient than the enclosed alternating-current lamp, nevertheless the alternating-current lamp has replaced the direct-current lamp, because it can be operated by stationary constant-current transformers from an alternating-current system, while the direct-current lamp requires a special generator, a constant-current Brush machine, and since each Brush machine cannot be built for more than 125 to 150 lights,

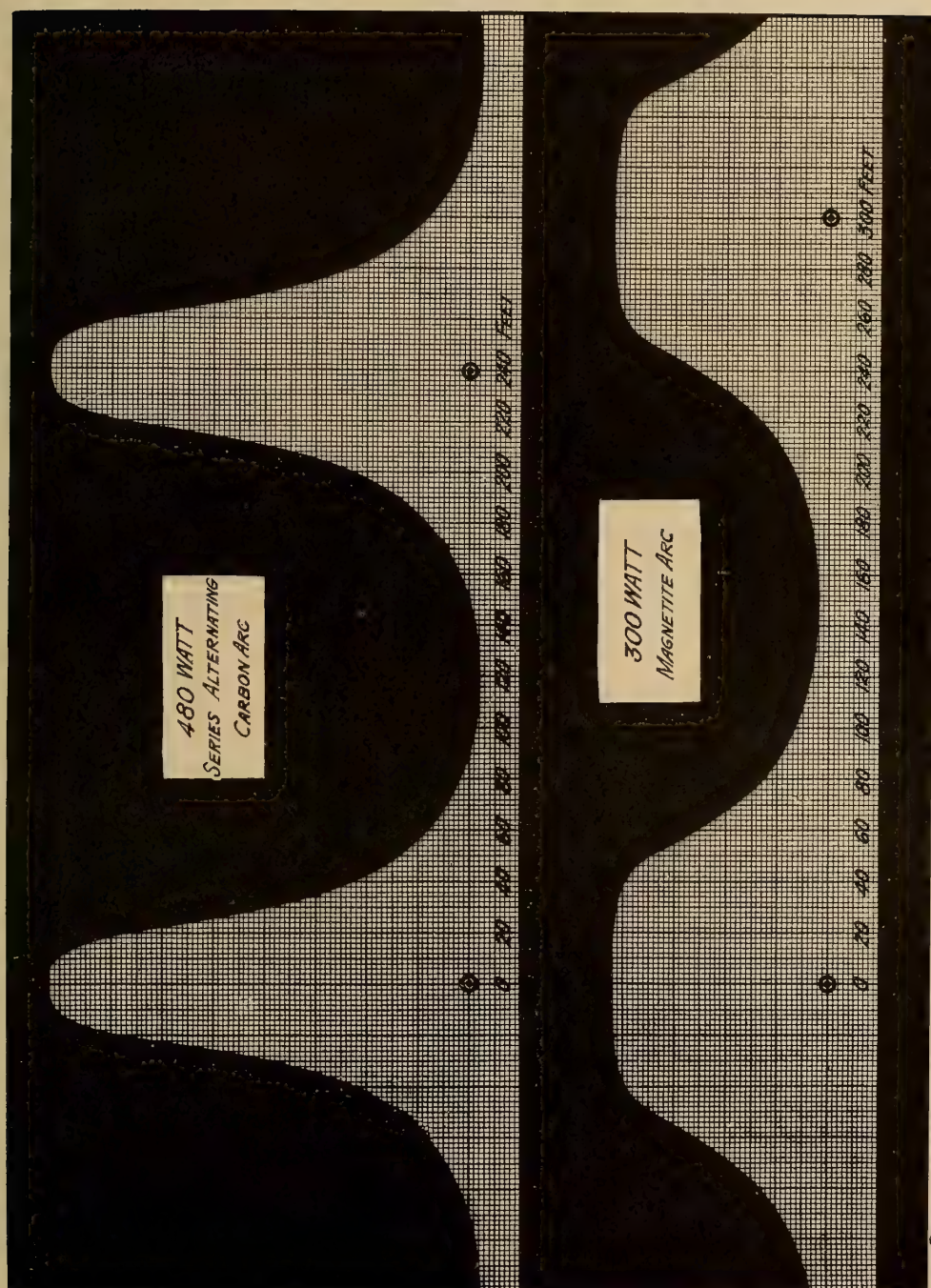


FIG. 2.—DIAGRAM SHOWING ILLUMINATION OF TWO STREETS EQUIPPED, RESPECTIVELY, WITH ORDINARY ALTERNATING CURRENT ARC LAMPS AND WITH MAGNETITE LAMPS

a large city requires a large number of small machines. This is expensive and inconvenient.

As the magnetite lamp requires a constant direct current, it was, in spite of its superior efficiency, much handicapped until the mercury arc rectifier was developed. The mercury arc rectifier is a small auxiliary apparatus inserted between constant-current transformer and arc circuit. It converts the constant alternating current into constant direct current,

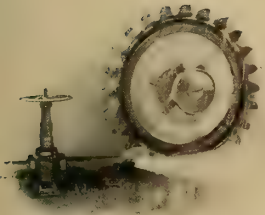
so that series direct-current arc lamps can, by means of the rectifier, be operated from a constant-potential, alternating-current circuit without moving apparatus, that is, apparatus requiring attendance.

Since the current is used as direct current, the frequency of the alternating-current circuit is immaterial. The constant-current rectifier circuit can, therefore, be operated from a 25 or 33-cycle system, as well as from a 60-cycle system.



RECENT HYDRAULIC POWER DEVELOPMENTS IN SWITZERLAND

By Enrico Bignami



SWITZERLAND has long been noted for its waterfalls and torrential streams, and this fact, together with the entire absence of coal deposits within its lim-

its, has led to the utilization of water power whenever practicable. To such an extreme has this been carried that in the republic, as well as in the adjacent French Department of Savoy, the masses of snow and glacier ice on the Alps from which the streams are supplied have been given the title of "white coal," since it is from this source that the power is derived which is rendering the importation of coal for power generation unnecessary.

Among the most recent of hydro-electric installations in Switzerland is that designed to utilize the power of the River Orbe, this stream forming the outlet of the basin of the lakes of Joux. These lakes, the Lake of Joux, properly so-called, and Lake Brenet, are situated in the Canton of Vaud, in the valley of the Jura Mountains, about 50 kilometres north of Geneva, at an altitude of 1000 meters above the level of the sea, this valley forming a sort of natural basin with an area of about 211 square kilometres. In this valley a portion of the rainfall and melting snow is absorbed directly by the ground, while the remainder gathers in the lower level, forming a body of water of about 10 square kilometres area, with a maximum depth of 34 metres. A contraction of the valley divides this body into two lakes of

unequal size, one called Lake Joux and the other Lake Brenet.

These lakes had no direct outlet, the water percolating through the rocks, according to the permeability of the strata, and gradually finding its way into Lake Rousses, from which the River Orbe takes its origin, the principal portion of the water being discharged through the crevasses on the side toward La Derrier, near Vallorbes.

Since these outlets varied in capacity according to the season, being sometimes almost closed by the freezing of the water, the level of the lakes varied, the records showing changes in level of 6 to 7 metres. These higher levels of the water became dangerous to the residents, and the regulation of the water level has been considered as a question demanding engineering control. Since there is a difference of about 230 metres in level between the surface of the lakes and the origin of the River Orbe, it naturally occurred to the engineers that the control of the level of the lakes might well be combined with the installation of a hydro-electric station.

The plan which has been followed is that suggested by M. A. Palaz, of Lausanne, this involving the construction of a canal to receive the entire discharge of the lakes and also supply the power house. In order that the regulation should be under complete control it was deemed necessary to close entirely the escape through the crevasses in the rocks, this being accomplished by the construction of masonry and concrete dams along the banks of the lakes at the points where the percolation



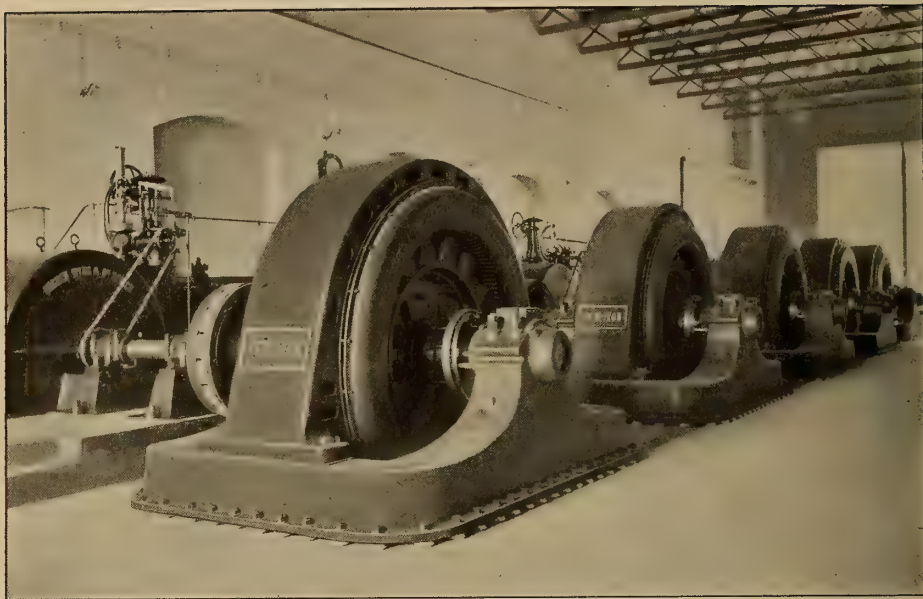
GENERAL VIEW OF THE POWER HOUSE AT LA DERNIER. SHOWING ALSO THE PENSTOCKS AND GATE HOUSE ABOVE

was known to take place. By providing a weir, with regulating gates at the inlet of the canal, the discharge has been placed entirely in the control of the engineers.

In general, the plan consisted in carrying a tunnel through the rocky ridge, and in constructing at the outlet of the tunnel an artificial forebay to receive the gates, regulating appli-



A VIEW OF THE VALLEY OF THE ORBE WITH POWER HOUSE ON RIGHT



FIVE OERLIKON ALTERNATORS IN THE POWER HOUSE AT LA DERNIER, SHOWING ALSO THE FLEXIBLE COUPLING AND THE WATER-WHEEL GOVERNOR

ances, trash racks, etc., and from which penstocks could be led down the side of the mountain to the turbine wheels in the power house.

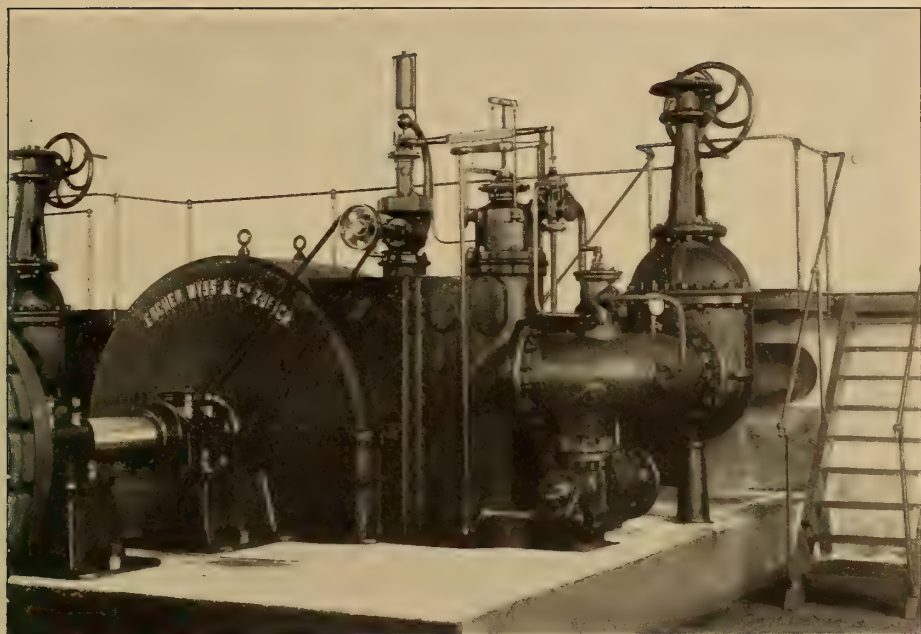
Under the new system of control the level of the lakes is maintained between 1005 metres and 1,008.50 metres above sea level, or a difference of 3.50 metres. The effective fall is 236 metres, or allowing for losses, the net available fall may be taken at 234 metres. Taking the efficiency of the turbines at 75 per cent., it is computed that a discharge of 430 litres per second is necessary to produce 1000 horse-power. With the water at the level of 1,008.50 metres the discharge is estimated at 2900 litres, developing 6740 horse-power, while for the level of 1007 metres the flow is 1600 litres, producing 3720 horse-power. These figures, however, are based upon a supply throughout twenty-four hours per day, while the demand actually being for shorter periods, the water may be stored to provide for a larger supply of power during the briefer time.

The requirements of customers tak-

ing power rarely exceeds ten hours per day, while the lighting load does not last more than from three to four hours, hence as there is ample pondage area, the power station can supply during the shorter load hours of each day a proportionally greater quantity of energy, and it is estimated that, based upon the average load factor of the tributary region, the power station can sell 15,000 H. P.

The present installation has been designed for a capacity of 10,000 H. P., the machinery for 5000 of which is now in place and operation.

At the lake level the canal tunnel through the hill is 2.20 metres wide by 2.60 metres high, cut through the native rock of the mountain and lined with concrete where necessary. At the headhouse the canal is expanded into a large masonry reservoir that impounds sufficient water to check the minor variations due to sudden changes in load, reduces the velocity of the water through the tunnel, collects any rubbish that may find its way from the lakes, affords oppor-



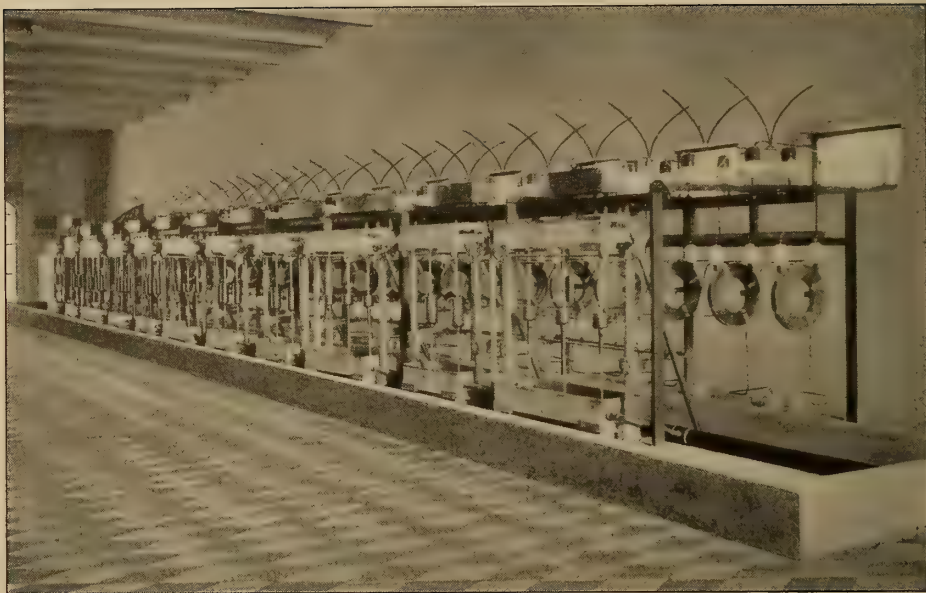
A 1600-H. P. PELTON WHEEL IN THE POWER STATION AT LA DERNIER, SHOWING ALSO GOVERNOR

tunity for all of the regulating apparatus necessary at the heads of the penstocks, and houses the necessary attendants required to manipulate this part of the plant. The headhouse has telephonic connections with the power station, so that at all times the attendants in both places may be in instant communication with each other. From the headhouse extend three penstocks. These are 850 millimetres in diameter, being built in sections, with flanged ends riveted together. There are three penstocks, the capacities of these being so calculated that two of them are sufficient to supply the present needs of the power station, leaving the three in reserve in case of emergency. One of the penstocks lies on the surface of the ground the entire distance from the headhouse to the power station, while the other two are buried in the earth for greater protection as soon as they reach the valley. Each penstock is divided into three parts and equipped with two expansion joints to provide for changes in temperature. These con-

sist of movable sleeves running into stuffing boxes. One end of each section of penstock is firmly anchored in the rock, while the other is attached to the sleeve, so that when expansion and contraction take place it moves in and out of the stuffing box that encloses it.

The power station, as is indicated in the various illustrations, is a substantial stone structure, built with all of the care, completeness of design and architectural proportions for which Swiss engineers are famous. It is entirely fireproof, being covered with a tile roof of the Münch system, supported by iron trusses, leaving the interior of the station entirely clear from all columns or pillars.

The dynamo room is 55 metres long, 12.50 metres wide by 10 metres high. It is designed to accommodate 8000 kilowatts of generators in 1000 horse-power units, together with their turbine wheels and the necessary exciter outfits. Over all of the machinery and under the trusses there is a longitudinal track that supports



GENERAL ARRANGEMENT OF CIRCUIT BREAKERS, SHOWING LIGHTNING ARRESTERS ABOVE

a 12-ton electric crane that forms a hoisting apparatus that can travel from end to end on the operating arm, of sufficient capacity to handle the largest single piece that enters into any of the machinery.

The generators and exciters were manufactured by the Oerlikon Company. There are five main generators of 1000 H. P. capacity, each being connected by a flexible coupling to a turbo unit of the Pelton type, built by Messrs. Escher, Wyss & Co., of Zurich. The generators are run at 375 revolutions per minute, and deliver current at a tension of 1350 volts and a frequency of 50 periods.

After completion, the generators were carefully tested by coupling two of the machines together in such a manner that one would operate as a generator driving the other as a motor. An overload of about 30 per cent. was imposed, and the test continued for eight hours consecutively. Temperature measurements showed that the generator coils did not rise more than 35 degrees Cent. above the atmosphere, and that both machines

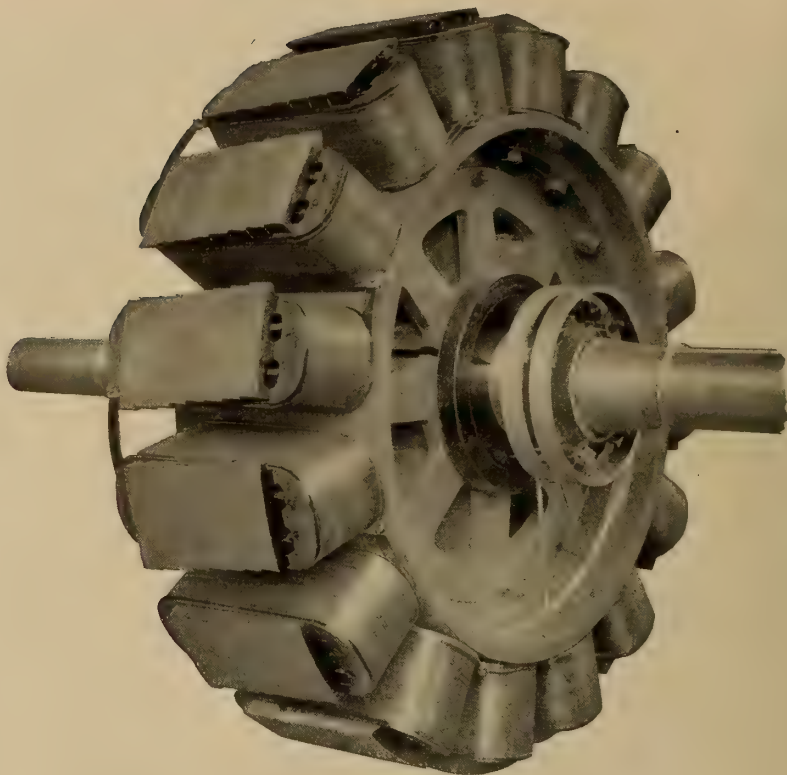
under this severe test responded perfectly in all respects.

The wheels operate under a head of 234 metres. As they are of the Pelton type, the regulation is secured partly by shutting off the water and partly by deflecting the discharge nozzles. For safety, check valves are installed at various points along the penstocks, so designed that in case the water flow is suddenly shut off a sufficient overflow may be provided, thus preventing injury to the penstock. These safety devices are further so arranged to provide an outlet for any air that may accumulate.

The exciter outfit at present consists of two units, each made up of a 150-horse-power turbine driving a direct-current dynamo. The exciter plant is arranged at one end of the generator station. The exciter wheels in all respects resemble those of the main generators, excepting that they are smaller. The governing mechanism is also similar, but somewhat more sensitive. As already stated, sufficient space is provided in the main room so that three complete



THE HEAD WORKS AND GATE HOUSE WITH THE UPPER PORTION OF PIPE LINES

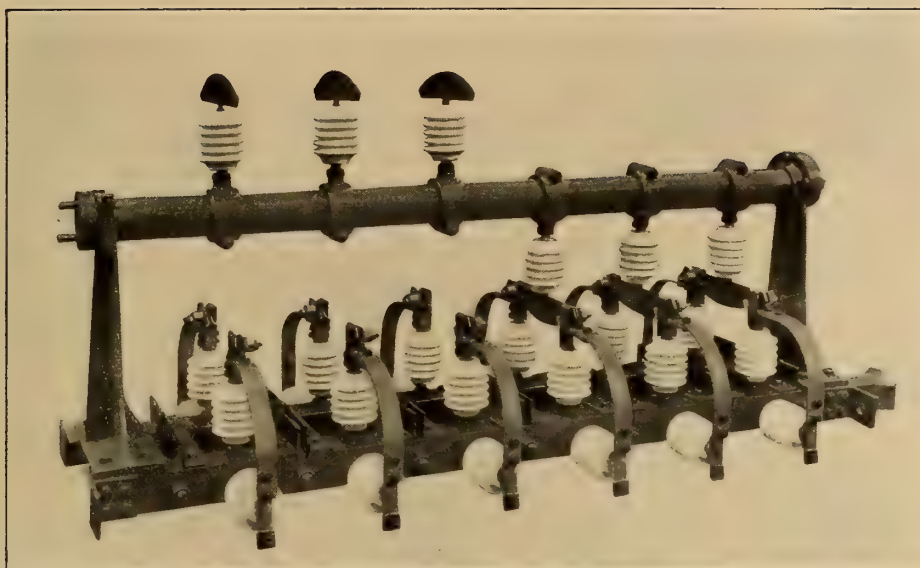


ROTOR FOR THE MAIN ALTERNATORS IN THE POWER HOUSE AT LA DERNIER

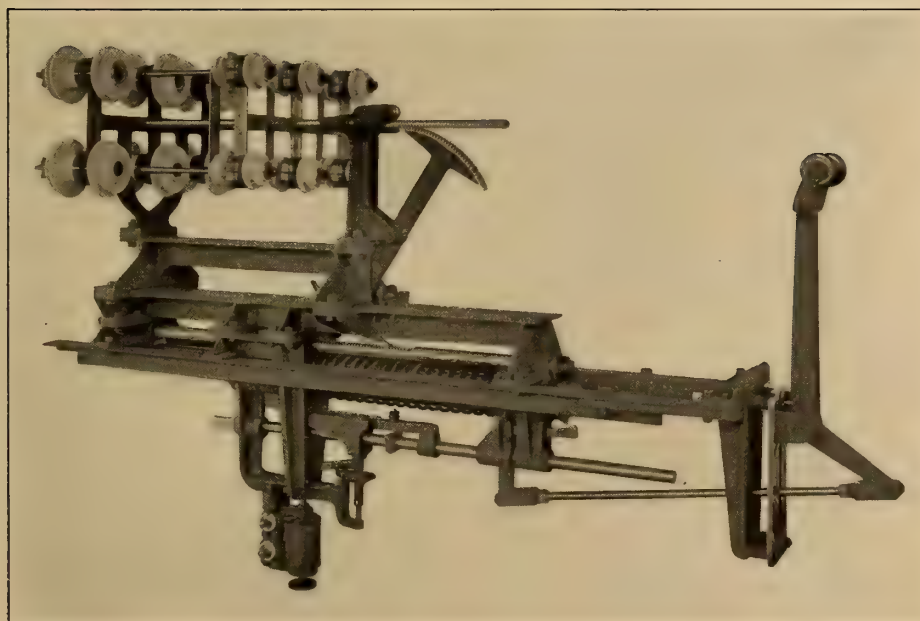
exciter outfits can ultimately be installed. One of the present outfits is sufficient to excite the generators now in operation, so that there is always a spare exciter rig. When the full generator capacity is in place two exciter rigs will be required, and then reserve capacity will be secured by installing one more outfit.

The proper switching apparatus must be provided in order that current may be delivered to the lines as required. The power station must be protected from lightning, the energy delivered by the generators and exciters must be suitably handled and controlled, and finally, in order to supply both single-phase current for lighting and tri-phase current for power purposes, it was necessary to resort to a somewhat complicated system of commutators in order to transform the generator output to the kind of current that is desired. All of

this mechanism must be under the control of the attendants and so located that the operation of the power station may be under the supervision of such an attendant as can instantly reach any desired switch. For this purpose the auxiliary apparatus is located at one end of the station. The switches are placed in fireproof compartments, somewhat below the level of the main floor. The switchboard is located upon a gallery above these, so arranged that the attendant can oversee the whole of the operating room, while the lightning arresters, choke coils, etc., are placed in a second gallery above the first. Each incoming circuit is protected by means of lightning arresters and choke coils. The arrangement of the protective devices, including the choke coils and lightning arresters of the horn type, is fully illustrated. The switches are not oil insulated,



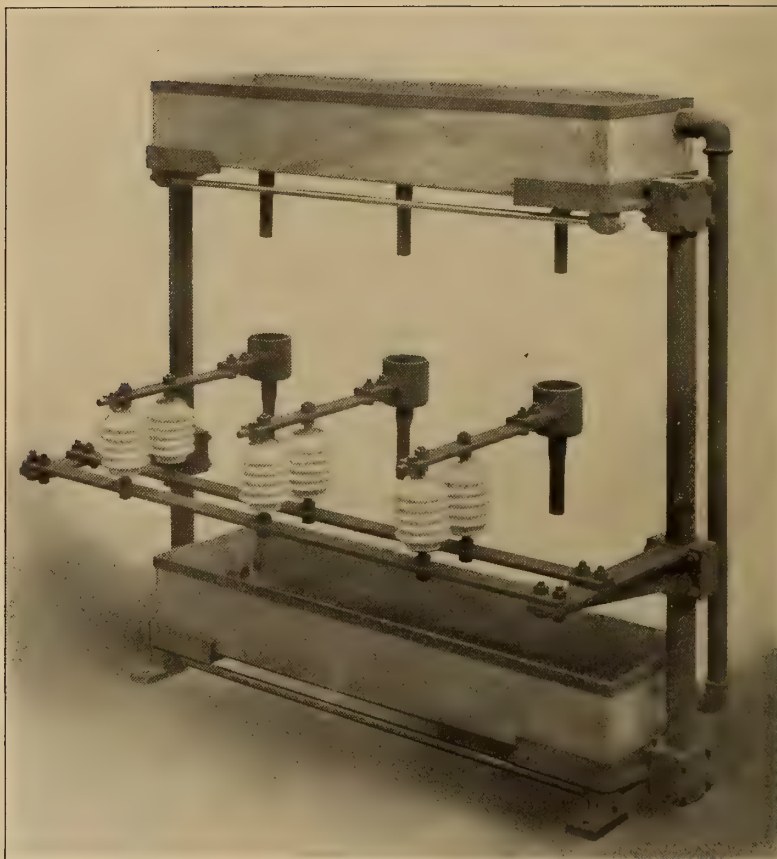
DOUBLE CIRCUIT BREAKER FOR THREE-PHASE CURRENT



AUTOMATIC HIGH-TENSION CIRCUIT BREAKER

but of the piston type; their design, however, is such that they can handle, without injurious arcing, the heaviest load to which they are likely to be subjected, and ingenious interlocking devices are provided so that it is impossible for the attendant to pull a

breaks it will be prevented from falling upon roadways or railroads. For some of the less important lines wooden poles are employed, but the widespread use in Europe of structural iron for the supports of important transmission lines is a

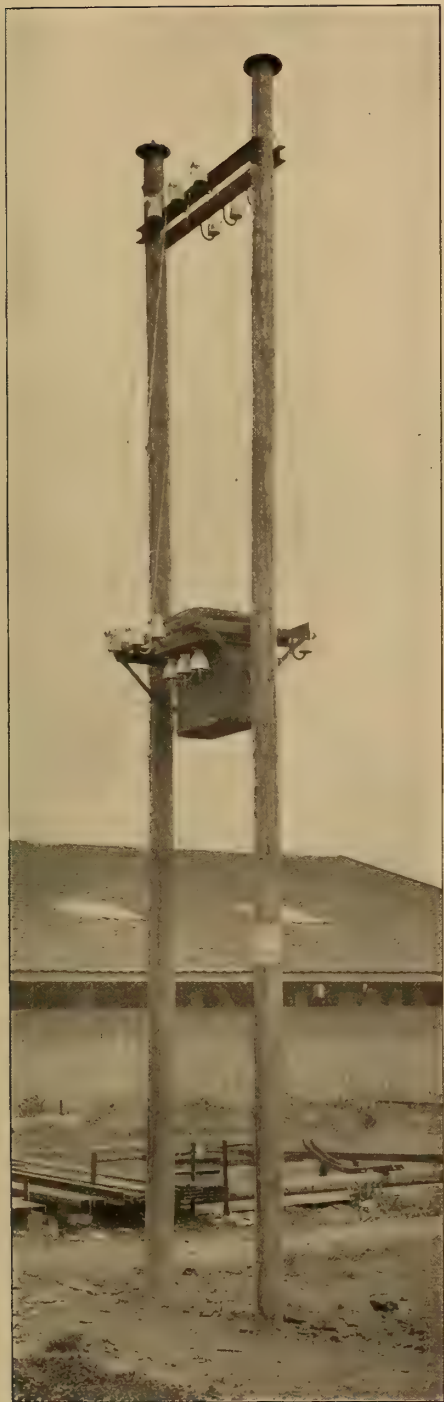


HYDRAULIC RESISTANCES FOR LIGHTNING ARRESTERS

wrong switch or to pull the switches in improper order.

From the power station transmission lines have been so built as to serve all of the adjacent territory. The line is placed upon substantial structural iron poles, firmly set in the ground upon concrete basis. There are two circuits, a single-phase and a tri-phase, one on each side of the pole. The circuits are carefully guarded, so that in case a wire

somewhat striking commentary upon the more careless American practice that rarely uses anything but wood. At the various villages the high-tension transmission lines stop, terminating in static transformer sub-stations, examples of which are shown in the illustrations. The type of sub-station depends upon the quantity of energy to be delivered; where this is small, the design employed consists merely in a transformer suitably located upon



AN OVERHEAD TRANSFORMER

substantial poles, placed so far above the ground as to be freed from the interference of the curious or malicious. When larger amounts of energy are needed the transformers are housed in a small building. In each case it will be noticed that two kinds of current are supplied, because both the tri-phase and single-phase lines are extended to the transformer sub-station. From each station a proper distributing system, at medium or low tension, is extended to the premises of the various consumers. Some idea of the importance of this installation may be gathered from the fact that one line, known as the Swiss circuit, is equipped with 235 transformer stations; it extends to and serves twelve separate villages, in which there are populations that aggregate about 92,000.

Much care has been exercised to secure efficiency of service by so designing the transmission lines that they form a network over each territory in such a manner that in case of accident to any one line the stations depending on it may be served by taking current from some one of the other lines. For this purpose the transformer stations are supplied with proper switching devices, so that the reserve lines can be cut in at pleasure. This plant has been in operation for about one year, and, so far, has given satisfactory and uninterrupted service.

The current is used at the present time in the various fields of lighting, power, and heating. The principal service is for incandescent lighting, only a few arc lamps being used. Current for heating is supplied, in connection with laundry work, for ironing.

The motors are operated either with single-phase current, at 250 volts, or three-phase, at 400 volts, according to the power demanded and the character of the industry. Much of the power is distributed for agricultural purposes, for operating threshing machines, and especially for the creameries, in con-



HIGH-TENSION TRANSMISSION LINE CROSSING RAILWAY TRACKS

nection with the production of butter and cheese. Experience thus far has shown that there is no difficulty in placing the motors in the hands of the farmers and other inexperienced persons, the simplicity of the apparatus rendering the results altogether satisfactory.

The reported cost of the installation has so far amounted to about 7,000,000 francs, and the company now proposes to expend some 2,000,000 francs more in increasing its capacity and extending its territory.

The Vaudoise Company do not, however, limit their activity to the

hydro-electric station just installed, but operate over a large territory in Switzerland, having at their disposal a number of plants, a list of which, together with their capacities, appears in the following table:—

The approximate hydraulic power actually at the disposition of the Canton of Vaud by the electric distribution of energy is as follows:—

	Horse-power
Commune of Lausanne	14,000
Société Romande d'électricité.....	10,000
Electric plant of Clef.....	1,500
Plant at Hauterive and Montboven.....	3,000
Lakes Joux and Orbe.....	12,000
Miscellaneous	3,200
Total	43,700

CONSTRUCTION INSPECTION OF BOILERS AND ENGINES

I.—BOILER INSPECTION DURING CONSTRUCTION

By J. R. Thompson

The duties of the inspector detailed to supervise the quality of material and workmanship given by the manufacturer in the course of the execution of a contract are both difficult and delicate. He is employed for the very purpose of securing a satisfactory fulfillment of the contract, and at the same time he should be free to exercise such judgment as shall not work unreasonable hardship to the honourable manufacturer who is endeavoring to execute the work in the spirit of the agreement and in accordance with the accepted state of the art to which the undertaking belongs. Mr. Thompson writes from a British viewpoint, but the principles involved in the questions are practically the same in all parts of the world, and apply to many other departments of engineering besides the specific ones here considered. The present article deals with the inspection of boiler work, to be followed by others upon the inspection of steam engines and upon testing.—The Editor.



A WELL-UNDERSTOOD clause in many engineering specifications gives the buyer, or his deputy, right of access at all times to the yard or works of the contractor; and the power to take or make such tests as shall be neces-

sary to remonstrate that the material, treatment, and workmanship are such as will fulfill the terms of the contract.

At the works of many firms executing orders from railway companies, great industrial concerns, municipal undertakings, or government departments, one or more permanent officials are regularly maintained, who watch the work through all its stages, and write up their reports daily throughout the year.

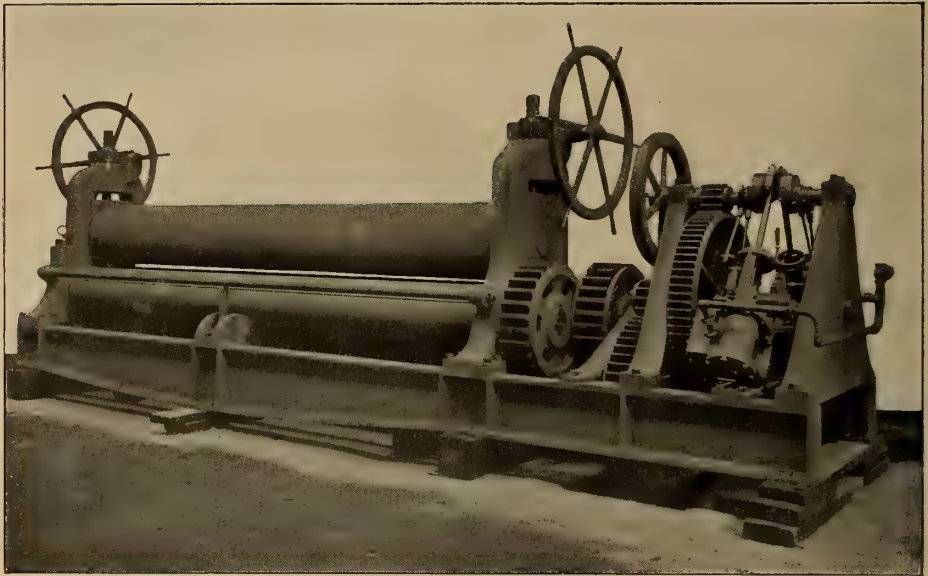
Taking the typical case of steam engines and boilers as an example, the duties of an inspector "during construction" fall naturally under three heads, Material, Workmanship and Efficiency, and it may be of interest to follow the procedure usually observed in such cases.

The requirements of the buyer are

generally set forth in the specification upon which the contractor's tender is based, but even if this is not the case, the usual requirements of first-class work are amply covered by the phrase which all self-respecting manufacturers insert in their own specifications in one form or another, "materials and workmanship to be of the highest class."

With the design of the machinery the inspector has little or nothing to do, it being understood that the contractor's drawings have already been examined and approved, either by the technical staff of the purchasing firm, or by their consulting engineer, or possibly by the expert of one of the numerous boiler insurance companies who make a feature of this class of work.

Boilers are made up of plates, strips, bars and rivets, supposed in the present case to be of steel. These are, therefore, the materials as regards the boiler, and are most conveniently inspected at the place of origin, namely, the rolling mills, if a thorough-going examination is desired. The "specification of plates" handed by the contractor to the steel manufacturer gives the dimensions of each plate and strip, and the full particulars of all angles, bars and rivet-steel, and all these materials are rolled to suit, being afterwards sheared

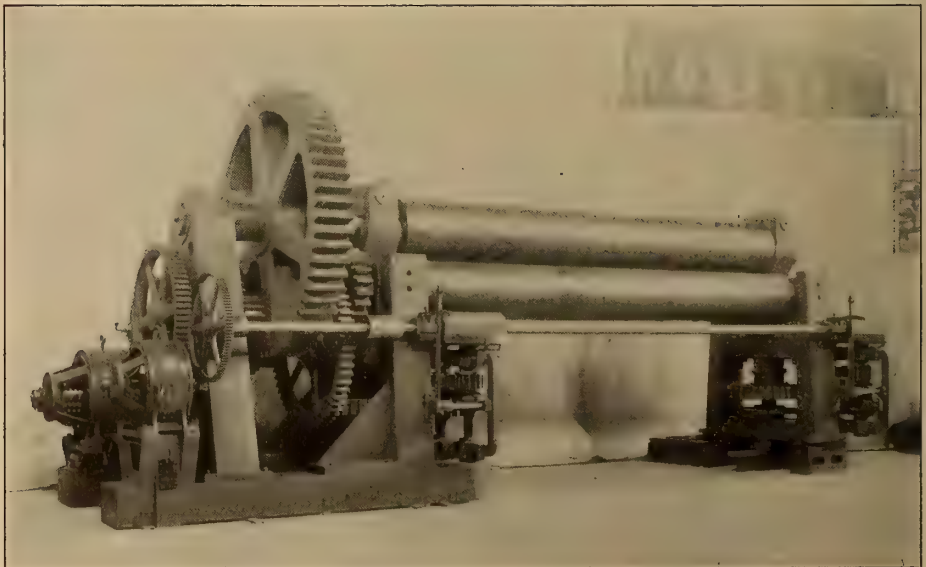


BENDING MACHINE FOR LARGE BOILER PLATES. FRANCIS BERRY & SONS, SOWERBY BRIDGE, ENGLAND

to make them the required size.

Every plate and bar is stamped while hot with a distinguishing number, as well as with the brand of the maker, and it will be the duty of the inspector, even if he does not witness the actual operation of rolling, to

see that the test-strips which are cut from each plate bear the identification marks connecting them beyond dispute with the plates whose qualities they are afterwards to demonstrate under the tensile bending, and possibly also analytical, tests.



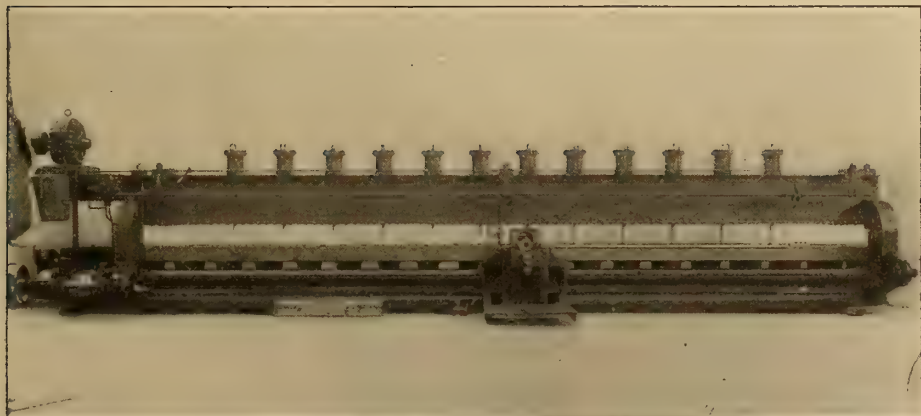
HEAVY PLATE BENDING ROLLS WM. SELLERS & CO., INC., PHILADELPHIA, PA.

The prescribed tests vary according to the requirements of the authority whose practice is adopted.

Taking the Board of Trade as an example of a prescribing authority, we have as the requirements for steel plate used in the construction of boilers for steamships carrying passengers the following tests, viz.: For furnace plates, 26 to 28 tons per square inch of section. Shell plates, 27 to 32 tons per square inch. A test strip to be cut

bent cold around a curve of which "the inner radius is one and a half times the thickness of the plates." If the plate is exposed to flame, it must previously have been heated to a cherry red, and then cooled in water at 82 degrees F.

These strips for testing should in all cases be carefully prepared, so that no indentations or scratches are left upon the surface or edges which might start a crack.



BOILER-PLATE PLANING MACHINE. WM. SELLERS & CO., INC., PHILADELPHIA, PA.

Arranged with pneumatic clutch system of driving, and with pneumatic clamps for holding the plate

from every plate, and 25 per cent. of these to be tested in the presence of a Board of Trade surveyor. The strips are machined to a form suitable for being gripped at both ends in the testing machine, with a plain portion between, usually 10 inches long by $1\frac{1}{2}$ inches wide.

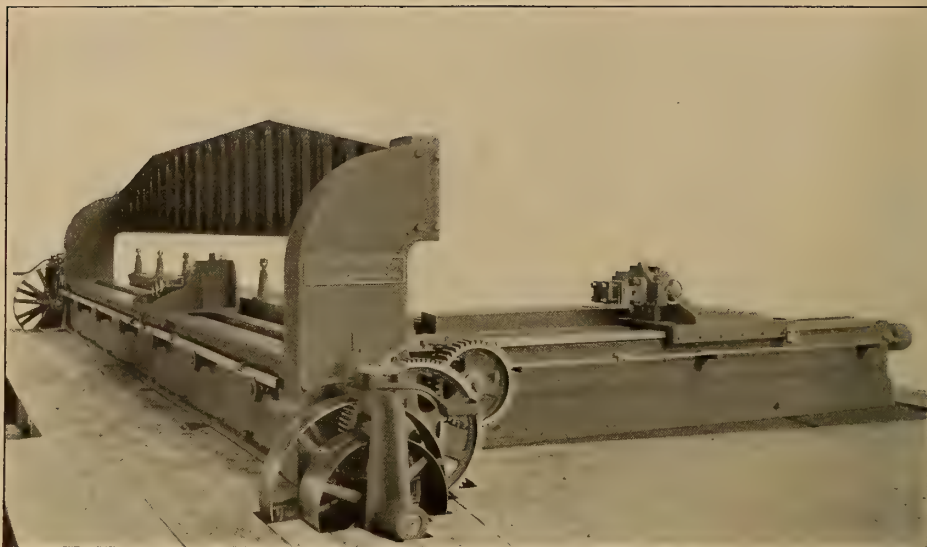
Upon being put to tensile strain the sample must break at a stress within the limit above mentioned, with a minimum elongation of 20 per cent. in a length of 10 inches. Upon the broken strip must be stamped, in addition to the identification number which it already bears, the breaking strain in tons per square inch of section, as well as the elongation. The letters B. T. are stamped by the surveyor upon all accepted test pieces.

In the bending test a parallel strip must stand without cracking, being

There is a very simple and easily applied test, not, however, prescribed by the Board of Trade, but frequently made use of by the inspector as a check. A strip of the steel in question 2 inches wide, having a hole five-eighths of an inch in diameter drilled through it, has to stand, without fracture and cold, the forcible enlargement of this hole to one inch and five-eighths diameter by the driving through it of a taper drift.

Butt-strips being in tensile stress breadthwise when in use, must not be cut from a bar, but from a plate of breadth equal to the length of the butt-strips, and of quality corresponding in all respects with the shell-plates.

Angle-sections are little used now in first-rate boiler work; wherever possible the plates should be flanged



DUPLEX PLANING MACHINE FOR FINISHING TWO ADJOINING EDGES OF BOILER PLATES SIMULTANEOUSLY.
NILES-BEMENT-POND COMPANY, NEW YORK

The end planing attachment is adjustable to plane 10 degrees either side of a right angle. This machine will plane plates up to 2 inches thick with plain rest, and 8 inches thick with compound rest

instead, but when their use is called for the tests may be generally similar to those for the plates.

Rivet-steel should be of about 25 tons tensile strength, and usually tests are made upon a certain percentage of the formed rivets at the works of the boilermaker, and will be referred to later on.

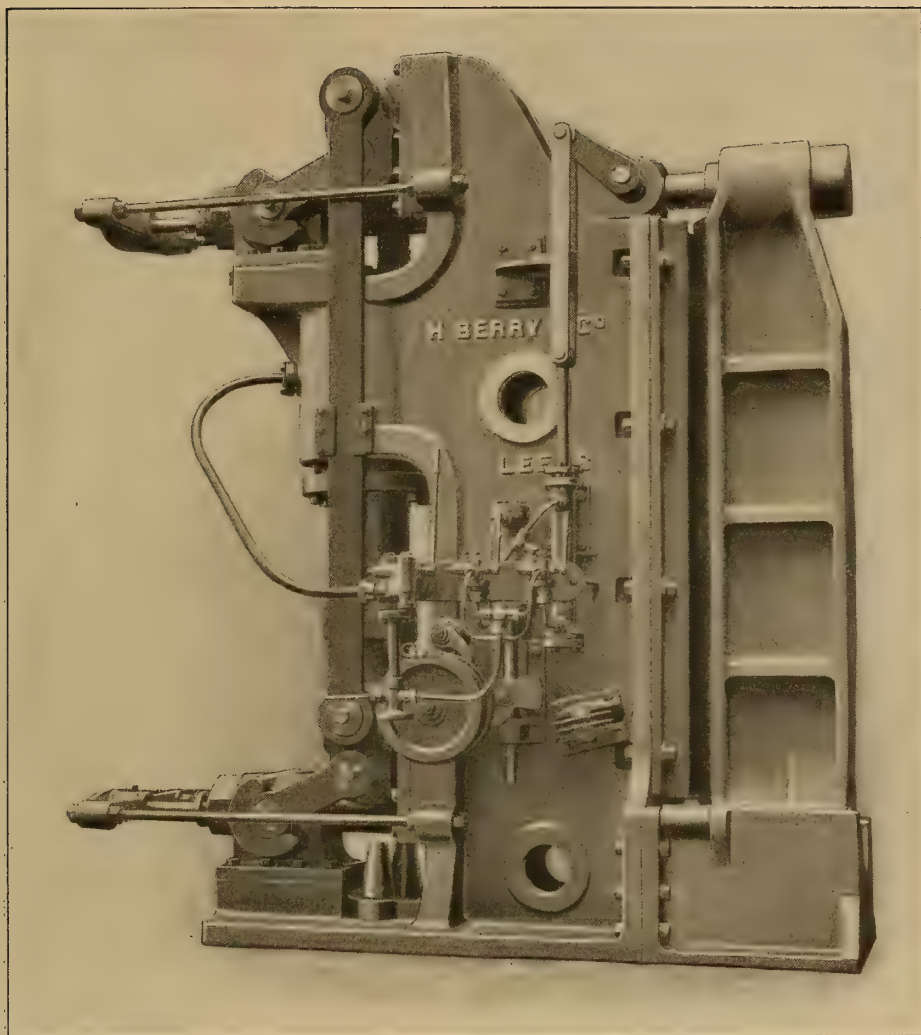
The inspector should satisfy himself at the steel works that each batch of plates corresponds with the specification in dimensions and that each plate is of full thickness, that they are properly flattened, and that every plate is stamped so that it can be identified and accepted at the boiler-makers' works, either by himself or by another inspector duly appointed for that purpose.

We will assume that all this has been fully carried out, that the various test pieces have yielded satisfactory results, and further, that any analytical tests specified have been made either at the steel works or by the purchasers. The material may now be considered as approved and ready for delivery to the boiler works,

where we shall now take up the running and follow the boiler to completion before making any reference to the engines, supposed to be proceeding simultaneously at the works of another contracting firm.

Our inspector, then, having received a notice from the boilermakers that the plates have been delivered and await his examination previous to any work being done upon them, duly attends, and being afforded proper facilities in the way of handling the plates, assures himself, from actual inspection of the marks, that these are the identical plates which were passed by himself or his colleagues at the steel works. Having certified to that effect, the boiler-makers are now free to proceed with the construction of the boilers.

Here we may break off for a moment to remark upon the imperative necessity which exists, on the part of the inspector, for a certain quality called tact. It goes without saying that while absolute integrity in the performance of the necessary duties of his calling is the bed-rock of the

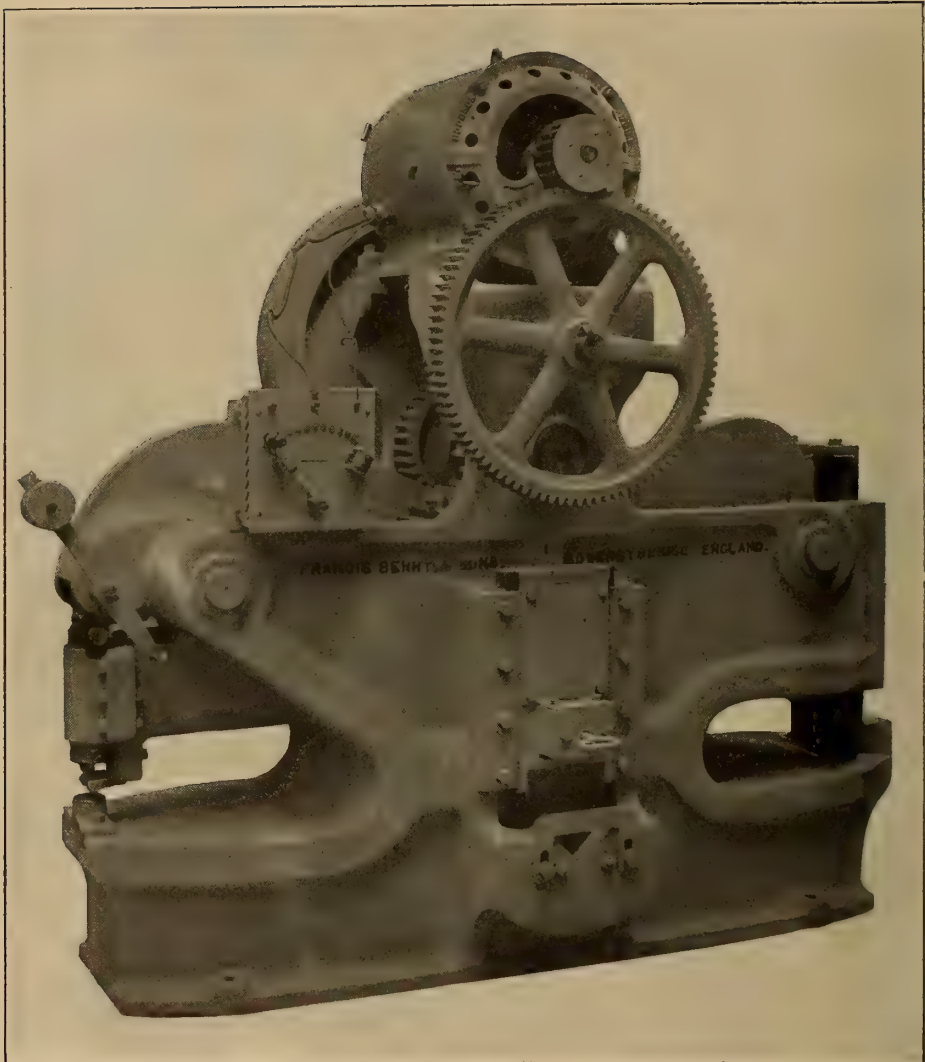


VERTICAL HYDRAULIC PLATE BENDING MACHINE, BERRY'S PATENT. HENRY BERRY & CO., LTD., LEEDS

whole system of delegated inspection,—we are not dealing with the class of individual who is accessible to bribes,—there are men on inspection work, honest and upright beyond question, who, not being endowed with the virtue of tact, create a feeling of irritation wherever they go, and, as a consequence, find their path beset with difficulties.

The man in whose hands is placed the power of responsible criticism needs a quick eye to detect shortcomings, a rapid decision in cases of

doubt, and the ability to discriminate between essential and non-essential deviations from the letter of the conditions. Intentional fraud,—the substitution of an inferior material or process, deception or concealment of a known, but invisible defect,—merits, and should receive, unhesitating condemnation, whilst an error of workmanship or accidental damage honestly reported by the contractor or his representatives may well receive due consideration, or even a suggestion of some means whereby total



COMBINED PUNCHING AND SHEARING MACHINE. FRANCIS BERRY & SONS SOWERBY BRIDGE, ENGLAND

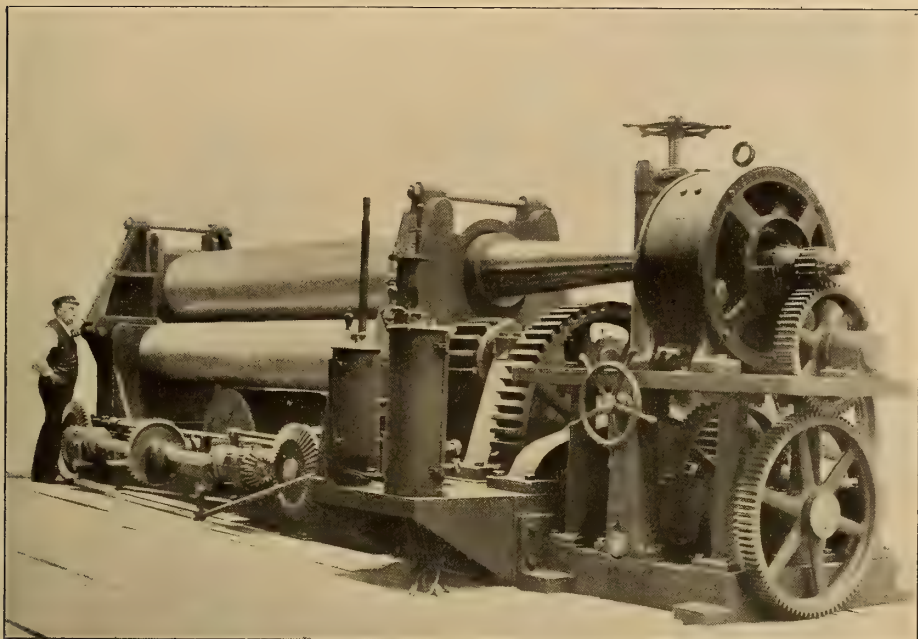
rejection may be avoided without actual injury to the purchaser.

But to return to our boilers:—

Some days or weeks later on, according to the size and number of the boilers, or the capacity of the boiler works for dealing with them, he will receive intimation that one or more boilers are “plated” and have arrived at the stage of “ready for drilling.” He will find the boiler, or the shell, at any rate, built up complete, the various plates composing it

being held together by “tacking-bolts” inserted in a few holes drilled here and there for the purpose, to be afterwards enlarged to form rivet-holes correct in size and position.

If the boiler be a large one, the shell may be put together only to a certain extent, that is, that although every two adjacent rings of the shell have been separately fitted together, each to each, with all inside and outside butt strips in position, yet the shell, as a whole, is too large to



BOILER PLATE BENDING ROLLS. NILES-BEMENT-POND COMPANY, NEW YORK

This machine can bend plates 12 feet wide and $1\frac{1}{2}$ inches thick. It is driven by a 50 horse-power electric motor, and the upper roll is raised and lowered by a 30 horse-power motor

handle in one piece, either for drilling or riveting, and will be presented for examination in two or more separate parts.

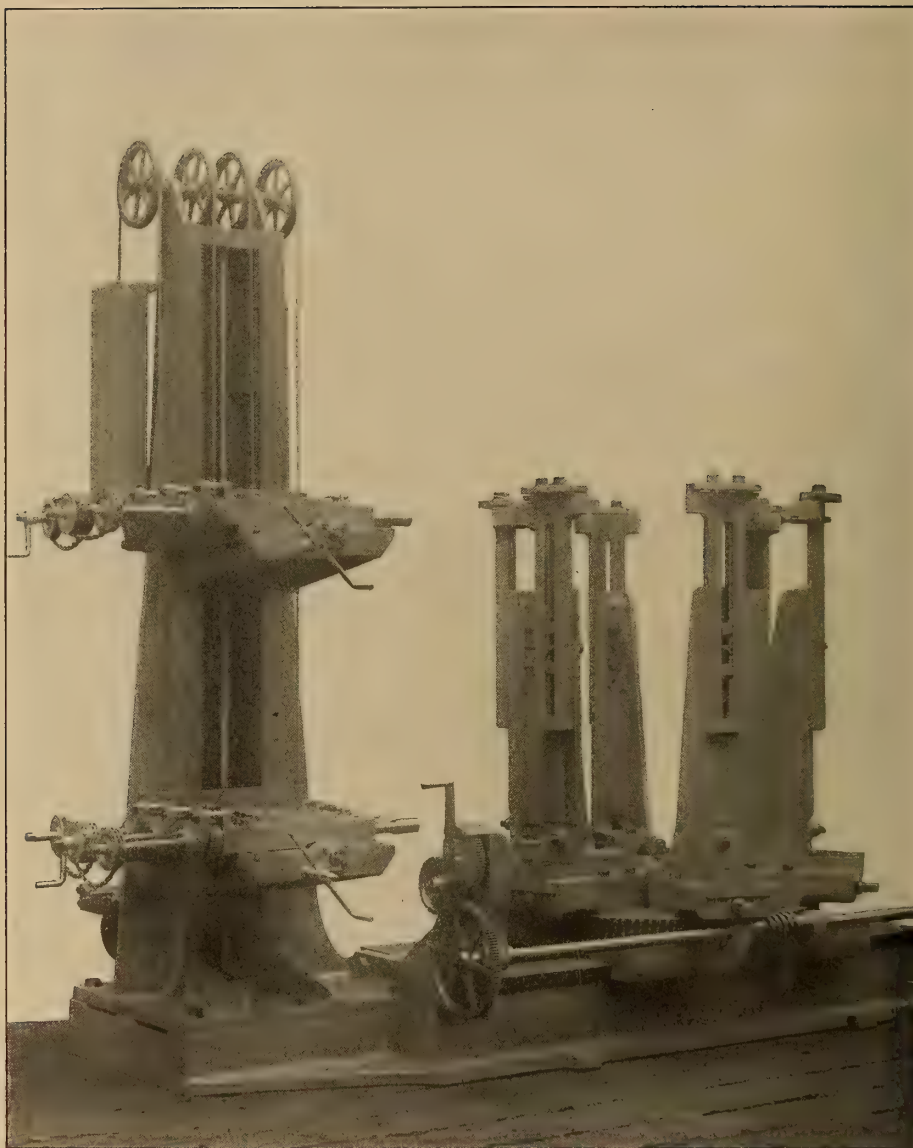
With the exception of the infrequent "tacking holes" already mentioned, the boiler is devoid of rivet holes, a proof, if such were needed, that the primitive method of punching has not been resorted to.

Assuming that the boiler in question is of the Lancashire variety, the inspector would expect to find the shell in two parts, each with its end plate in position, the two rings or belts of plates adjacent to the centre of the boiler's length having been already fitted together and taken apart. Each of the two parts into which the boiler shell is temporarily divided is carefully put down on levelled blocks, so that it can be readily examined within and without.

All the butt strips or the internal and external covering plates of the longitudinal seams are in place, and are duly curved so as to bed fairly

on the plates. Each ring or belt is, of course, in one piece, and being alternately large and small, each forms a circumferential lap joint with its neighbours.

The longitudinal seams should be placed alternately on each side of the centre line, high enough to clear the brick work, but not high enough to be in the way of the manhole and stand-pipes on the top of the boiler. Before being rolled into circular form each plate has been planed on the edges at an angle of about one in eight, while the length of each, whether it be an "inner" or an "outer" ring, has been so accurately measured that the ends exactly meet, forming a close butt joint under the covering strips. Again, the circumferential lap-joints, whether viewed from the outside or from the inside of the shell, are, or should be, a close-gripping fit all round. Each half of the shell, usually consisting of four rings of plates, should show, by the application lengthwise of a



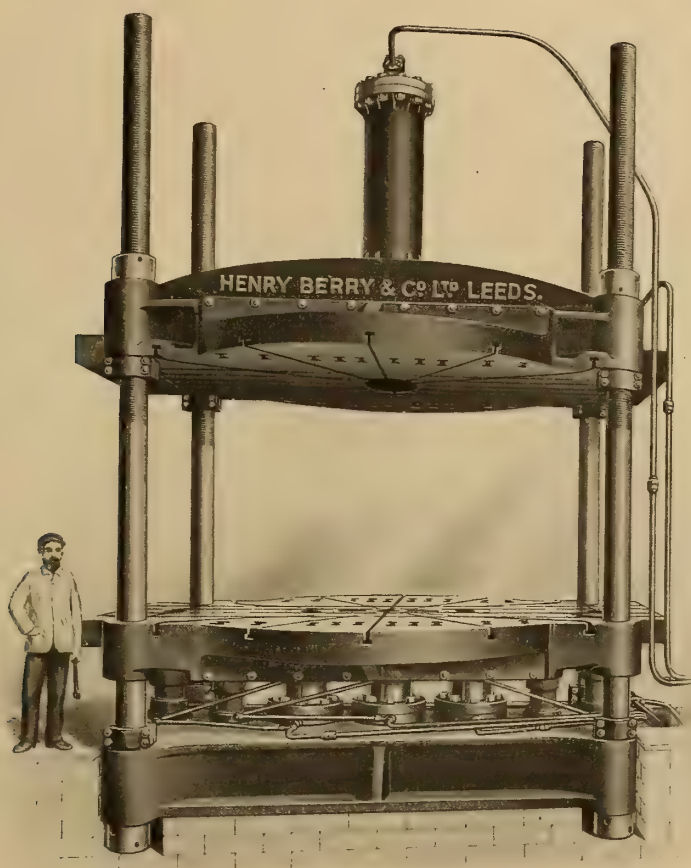
BOILER SHELL DRILLING MACHINE WITH SIX SPINDLES AND AUTOMATIC DIVIDING ARRANGEMENT. CRAVEN BROS., LTD., MANCHESTER

long, straight edge or a taut line, that the structure, as a whole, is built in a straight line.

The front end-plate, turned to its proper diameter, and with the flue holes flanged outwardly to receive the flues, and the oval manhole below duly cut out, is in place, attached to the shell by an angle ring of stiff

and heavy section, which should be bored and faced.

The back end-plate is usually flanged to enter the shell, forming a ring seam with it. In very many cases this construction is adopted for the front plate also, thus dispensing with the angle ring already mentioned. The flanged plates should be



HYDRAULIC FLANGING PRESS. HENRY BERRY & CO., LTD., LEEDS

turned to fit the shell, and the edges should be bevelled to one in eight for fullering.

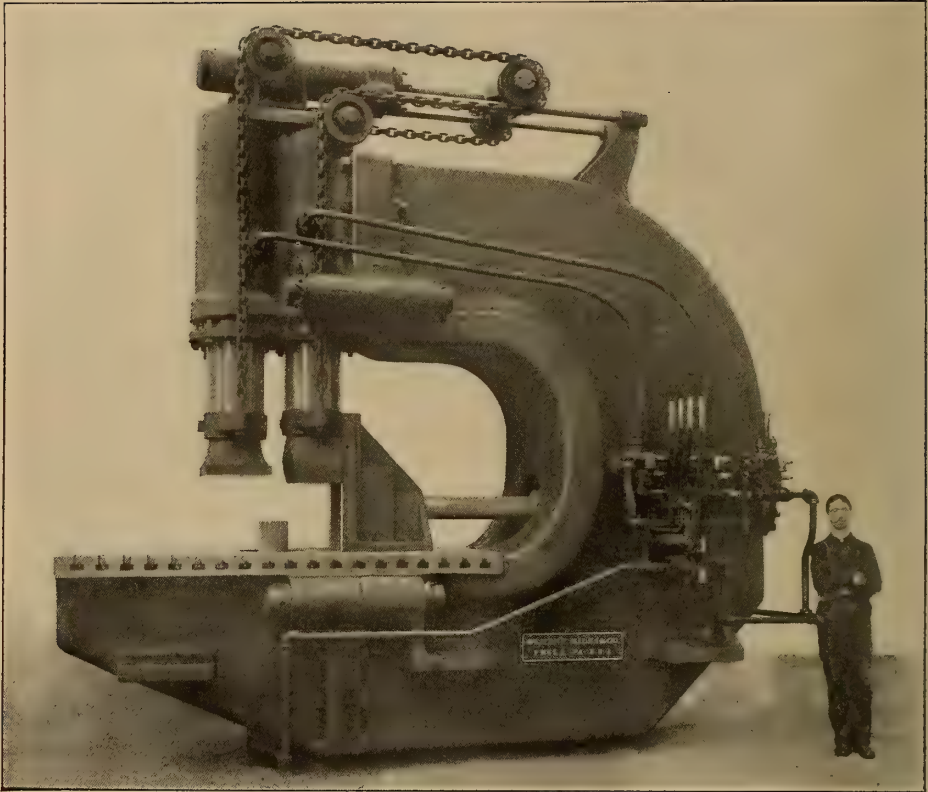
The gusset stays, if this method of staying the ends be adopted, are marked up in position, each gusset plate between two angle irons. The number, size and position of these are, of course, settled by the approved drawing to which the contractor is working, but the inspector is quite justified in seeing that no gusset or stiffening stay comes nearer to the flue than 9 inches, and that they are disposed concentrically as regards the flues.

If there be a radial distance of 10 inches between the nearest rivets of the gusset angles and the flue, so

much the better, as it is most important that sufficient provision be made for the ends to yield a little to the expansion of the flues.

The size, kind, and position of the various mountings specified to be riveted on the boiler should be checked over to correspond with the drawing, the correct and exact leveling of each being the subject of investigation later on after riveting.

Each plate should bear the maker's brand, the distinguishing number, and the stamp denoting that it has passed the prescribed tests, as already mentioned. The workmen will have chalked or painted a white ring round each mark for easy reference, and it will be the duty of the in-



SECTIONAL HYDRAULIC FLANGING MACHINE. NILES-BEMENT-POND COMPANY, NEW YORK

This machine is arranged for a variety of work requiring but a few formers. The vertical rams exert a pressure of 100 tons each, and the horizontal ram 50 tons. The vertical stripping ram removes the flanged pieces from the dies.

spector to satisfy himself that all the plates used are actually those which have been already passed by himself or his colleague at the rolling mills.

Should one of these tested and certified plates have been lost or damaged, or have turned out badly in flanging, notice to that effect will have been given by the contractor, and a new plate in substitution will have been rolled, sheared and tested.

Local heating of plates or butt strips for the purpose of thinning or otherwise should not be permitted without subsequent annealing, the more modern practice of reducing the thickness by planing or milling being far preferable.

So far as the shell is concerned, there is little more to see to at this

stage. It is well, however, just to check over the length and diameter of the boiler, the former being measured between the end plates inside and the latter inside the smallest ring of plates.

The flues next demand attention. The two flues of a Lancashire boiler are made up of a considerable number of rings (generally nine to each flue in a 30-foot boiler), each of which in its turn is composed of a single plate bent into circular form, having the lap-joint welded, preferably by a special gas-heating furnace and a power hammer. The plain tube thus formed is then heated at one end and rapidly revolved in a flanging machine, which turns down the end to form a flange at a single



ANGULAR FLUE-FLANGING MACHINE. HENRY BERRY & CO., LTD., LEEDS

heat. The same treatment being accorded to the other end, the flue section or ring is complete, only needing the annealing process.

By this method the flanges are true as if faced in a lathe, the edges, however, being turned to diameter.

Between every pair of flue flanges a narrow circular ring is placed, forming the well-known Adamson joint, a most simple and convenient method of providing the necessary longitudinal elasticity, combined with stiffness in a radial direction, to resist collapse.

When any form of corrugated furnace or flue is specified, the whole flue or furnace is supplied complete by the makers, who guarantee the strength in terms of the ultimate collapsing pressure.

In a Lancashire boiler having ordinary Adamson flues, the pair of flues should be so arranged that their respective joints do not come abreast of each other, or of the wing seams in the shell.

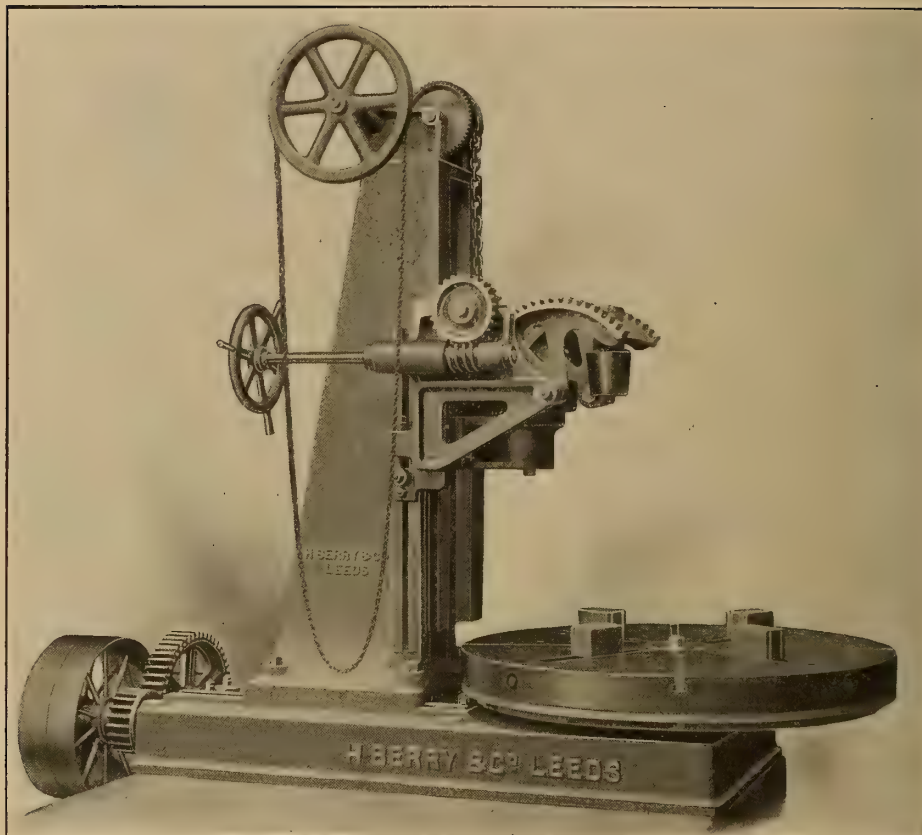
The front ring of each flue is left

cylindrical (i. e., not flanged) where it enters the flanged hole in the front-plate, so as to allow of the flue being passed into the boiler.

The back end flue ring is smaller in diameter than any of the others, and is flanged to form its joint with the back end-plate of the boiler, the last ring but one being made taper, to join up the differing diameters. By this arrangement it becomes possible for a man to pass between and underneath the two flues for cleaning or examination at any time.

All these points having been examined and approved, the boiler may be declared "passed for drilling," and we may leave it for a while to examine the rivets which are awaiting inspection, having been made from the round bars which have been tested and stamped at the rolling mills, as already described.

Rivets are made at a prodigious rate by a self-acting machine, and the attendant, with a couple of boys to help him, has fifteen or twenty bars in the furnace at one time.



BOILER FLUE-FLANGING MACHINE. HENRY BERRY & CO., LTD., LEEDS

It is not surprising, therefore, that rivets are sometimes made at too high a heat. It being impossible to test every rivet, all the inspector can do is to select at random from various parts of the heap, perhaps a couple of dozen samples, which he then proceeds to torture in the following manner, some in one way and some in the other:—

The head of the rivet, or rather the tail (for the head is formed by the hydraulic machine only when the rivet is closed on the plates), is heated and smashed out flat until its thickness is only one-eighth of an inch. It should stand this without cracking at the edges.

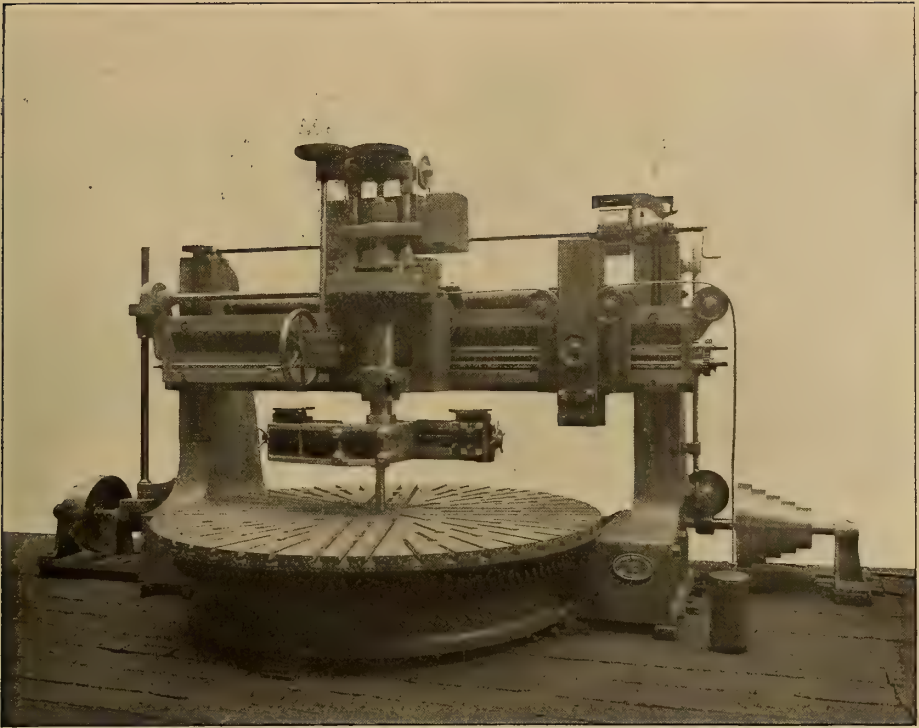
The shank of any rivet should stand doubling over on itself cold without the minutest sign of a crack

appearing on the outside of the bend.

The inspector usually either takes possession of a few of these samples, having stamped each with his private mark, or requests the contractor to forward same to his principals.

All rivets should be a fairly easy fit in the sized hole for which they are intended, being made a shade less than the diameter of the rivet holes, which are always drilled to standard dimensions.

The machinery for drilling the boiler shell in a well-equipped boiler shop usually consists of three or more horizontal drill spindles operating radially round a large revolvable base plate, to which the part or the whole of the shell under treatment is secured. The pitch of the holes in plain ring seams is accu-



MACHINE FOR TURNING BOILER ENDS AND CUTTING FLUE HOLES. CRAVEN BROS., LTD., MANCHESTER

rately divided, and the holes are always drilled through the two plates forming the joint in position.

In the transverse or longitudinal seams the drill passes through the covering plates or butt-strips, as well, or through four thicknesses of plates. The angles for gussets and the man-hole ring, with its inner doubling plate, are also drilled through in position.

The flue flanges, in pairs, with the flat ring between are also drilled straight through at one setting by a machine with a dividing arrangement which pitches the holes, so many to the circle, with perfect uniformity.

In an establishment fitted with plant of this character, it is hardly necessary to remain for a formal inspection of the drilling, the operation being so rapidly performed that probably enough of it can be done before the inspector leaves for him to judge of the character of the work.

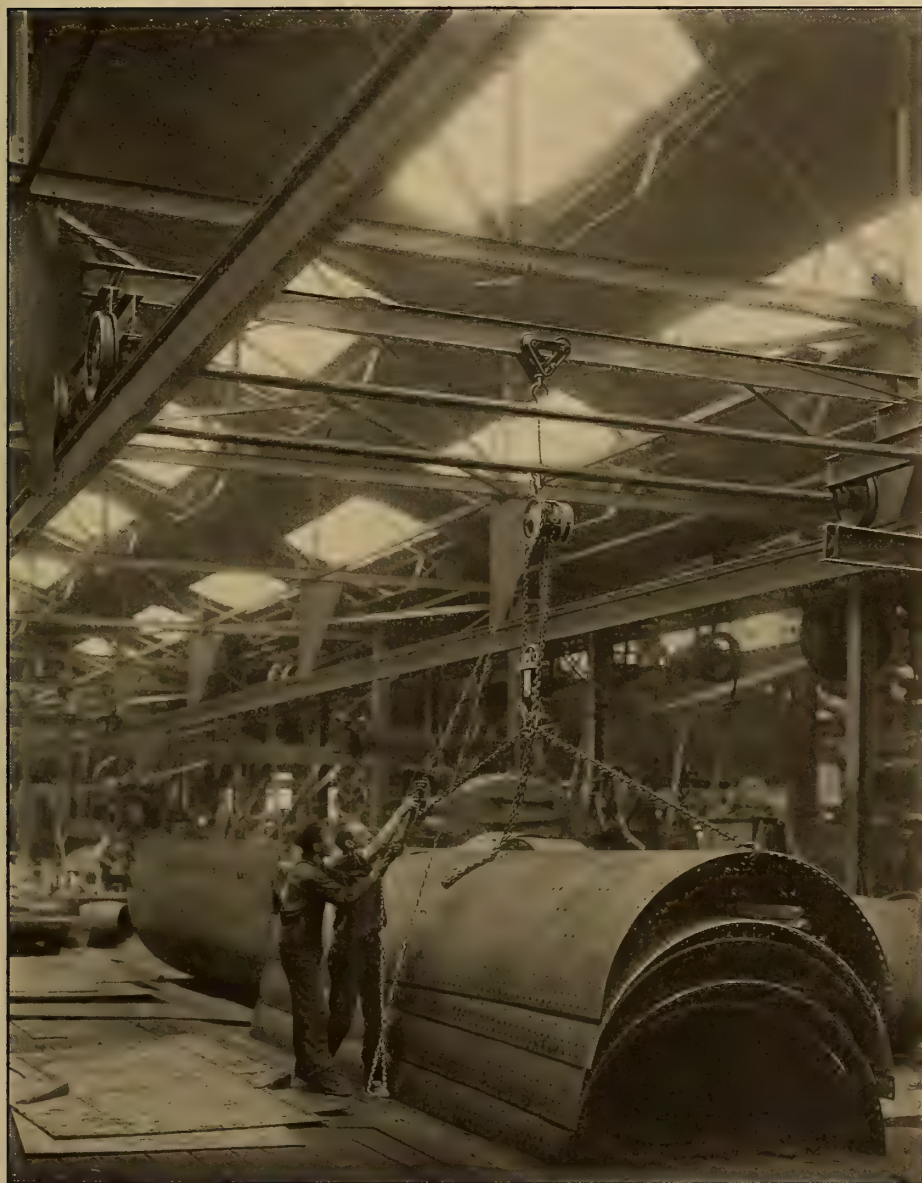
As each section of the boiler is drilled, the plates are separated, and the burrs which form round the edges of the holes are removed, either by slightly countersinking or by a hand tool which peels off the burr. This, though a minor operation, is one of great importance, as these apparently trifling burrs, if not removed, are sufficient to prevent that intimate contact of the plates necessary to ensure a perfect joint.

The specification probably contains a clause prohibiting the "drifting of rivet holes," a survival of the bad old days when the holes were punched before the plates were bent, and the ill-matched rows of rivet holes were forced into coincidence by the drift or "persuader." The use of such an instrument in these days is barely conceivable, but should a slight want of coincidence show itself, the passing of a full-sized reamer through the offending holes is productive of

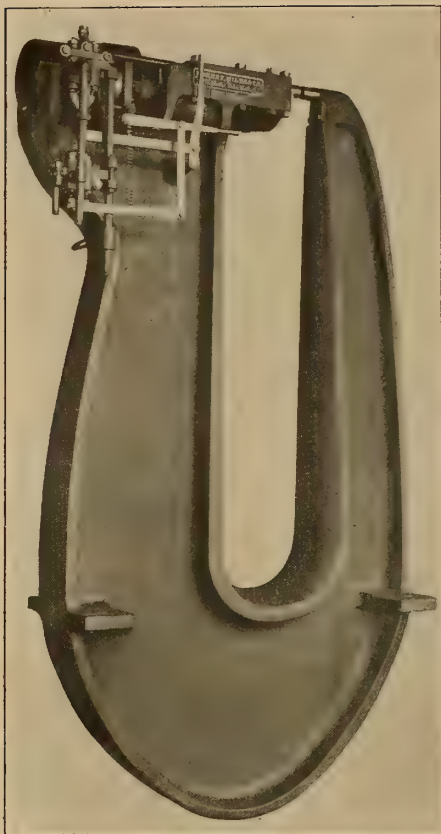


OVERHEAD TROLLEY TRACK AND YALE & TOWNE ELECTRIC HOIST AS USED IN THE ERIE CITY IRON WORKS

The overhead track supplies a number of cranes serving the various machines. The extent to which the hoist may be operated at an angle is shown



HANDLING MATERIAL IN THE BOILER SHOP. YALE & TOWNE TRIPLEX CHAIN BLOCK AND LIGHT OVERHEAD TRAVELLER HANDLING BOILER PLATES



SINGLE-PRESSURE HYDRAULIC RIVETING MACHINE,
CAPABLE OF EXERTING A PRESSURE OF 75 TONS
ON RIVETS $1\frac{1}{2}$ INCH IN DIAMETER. NILES-
BEMENT-POND COMPANY, NEW YORK

no harm whatever,—in moderation.

In a circular seam, for example, if we were to start riveting at one point and attempt to work consecutively round to it again, we should soon find that the outer ring of plate was gradually gaining on the inner one, owing to the tremendous closing pressure of the rivets, and that the holes were rapidly becoming less and less coincident.

To obviate this, it is usual to insert one or two rivets in each quadrant of the circle before proceeding to rivet regularly round the seam. By this means the holes are kept fair all the way round.

Gradually the component parts of the boiler shell are positively united,

the complete flues are rolled into place, the front end-plate being the last piece to be added, and the ring seams round the flue ends the last joints to be riveted. With very few exceptions, the whole of the riveting is done by machine.

The correct shank length of the rivets for plates of given thickness is pretty well known by experience, any error in this respect manifesting itself in the head being insufficiently formed, or by an unsightly fin being left round the head. Slight evidences of this latter there will always be, but too much of it is discreditable to the boilermaker and should not be passed by the inspector, who, in such a case, would order the rivets to be properly trimmed round.

No caulking of the plate edges is permissible,—that practice belongs to the drifting age, and, with it, has passed out of use.

The plates, bevelled to a slight angle, are “fullered,” or hammered with a broad, flat-faced tool, taking the whole thickness of the plate, in contradistinction to a caulking tool, which has a thin edge, and acts by tucking in a narrow strip of the edge, thus operating as a powerful means of wedging the plates apart.

The fullering is ordinarily done by a hand tool operated by compressed air.

The boiler, now supposed completed, is ready for the hydraulic test, and upon the day fixed by the contractor the inspector attends for the last time to witness the test and to examine all the fittings.

The duration and the pressure of the hydraulic test are prescribed by the specification, and it will be the duty of the inspector to closely examine the boiler shell externally and the flues internally, and satisfy himself after the test has been on not less than fifteen minutes that no leakage or “weeping” is apparent.

We have already mentioned that the gusset stays by which the flat ends of the boiler are stiffened should not approach within 9, or preferably



HEAVY RIVETING MACHINE. WM. SELLERS & CO., INC., PHILADELPHIA, PA

10, inches of the flues, and that they should be arranged concentrically with respect to the latter.

In estimating the deflection of end-plates when under pressure, it should be remembered the object of keeping the gusset stays away well from the flues is to definitely allow of a certain amount of breathing-room, in order that the expansion and contrac-

tion of the flues when in use shall not distress the end plates of the boiler.

Again, a small deflection even in the upper part of the end-plates is to be expected as the gussets come into tension. Too great rigidity is a vice, not a virtue, in flat boiler ends.

A general survey of the various

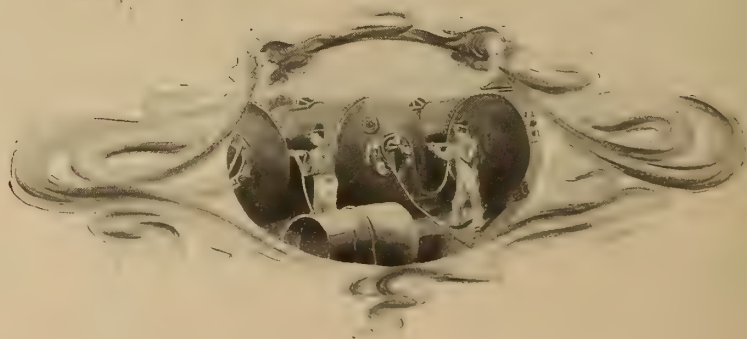
steam and water valves, which, under the head of fittings, are mentioned in the specification, may now be made. These should all be in place and under the specified hydraulic pressure, to demonstrate their strength and tightness under test. The bend carrying the blow-off cock should be specially examined. Being usually a steel casting, it is no doubt abundantly strong in relation to the test pressure, but it is worth while to give it a good dressing all over with a hand hammer while under pressure, a treatment which sometimes reveals a hitherto unsuspected small flaw.

The "stand-pipes" or necks, riveted to the boiler, which form the basis of the safety valves, steam valve, feed valves, etc., are, together with the manhole ring, of mild steel. These need little attention, save to make sure that each one is level and central. The furnace fittings, as grate bars, dead plates, dampers, etc., should be checked over, also the furnace fronts and fire doors, which should now be shown to the inspector fitted in their proper places. The fir-

ing tools also, and whatever spare parts or fittings there may be, should be examined and compared with the specification. Should the latter include a surface blow-off arrangement, the scum-pipes and troughs, together with their brackets or hangers, should be produced and examined, also the perforated feed dispersion pipes, if any.

If all the foregoing points have received proper attention, and there are no remarks to be entered against the contractor on the score of delayed delivery, the inspector may fill in his certificate that the boiler and all its appurtenances are in perfect order, and that the terms of the contract have been satisfactorily complied with.

This example of systematized boiler inspection through all the stages of construction, though specifically applied to the Lancashire type, may be taken as a fair sample of the tests and observations necessary as a control during the progress of any analogous kind of boiler of first-class quality.



SMOKE PREVENTION IN THE POWER HOUSE

By C. H. Benjamin



IT speaks well for progress that in these first years of the twentieth century one can make bold to talk of smoke prevention in connection with the economic production of power. All these hundred years from 1800 to 1900 A.D. the usefulness of steam has broadened and deepened, engines have grown larger and more complicated, boilers have differentiated, pressures and temperatures have increased. Compounding, jacketing, superheating, water-tubes, and forced

draught have all had their part in raising the standard of performance.

But in and through it all has been the one motive of making a ton of coal do more work and do it quicker, without much regard to the possible consequences.

The carbon and the hydrogen had done their work, and no one cared what became of them after that. Plumes of black smoke wreathing the tops of the stacks were badges of industry, and more smoke meant more work.

Even the advertising pictures in catalogues and periodicals were incomplete without this inky foliage, the natural accompaniment of factory chimneys.

When some few individuals, more æsthetic or less utilitarian than their neighbours, objected in a mild way to the gradual submersion of the surrounding landscape in a sea of by-

products, the manufacturers deplored the damage, but showed that it was inevitable, and that one must choose between smoke and a shut-down.

As the gradual extension of manufacturing industries over our Central and Western States brought to the surface the free-burning bituminous coals with their rich hydro-carbons, the inky cloud grew blacker and thicker until even the manufacturer began to take notice and wonder if something could not be done.

It is not probable, however, that his intermittent prickings of conscience would have spurred him to any very earnest efforts at betterment had it not some time occurred to him that there might be heat units somewhere in the cloud, a silver lining which he could not afford to lose.

The canny arguments of the smooth-tongued inventor of smoke-preventing devices for a long time failed to move him, but when some chance experiment at his own plant or that of a neighbour showed smoke to be an economic as well as an ethical mistake, his conversion was rapid.

It may as well be understood first as last that smoke abatement becomes a commercial reality when it saves fuel, and not till then. At the risk of repeating what most engineers already know, the reasons why it does save fuel will be briefly explained.

Smoke to the denizen of any city in the soft coal region does not mean the ordinary products of combustion, but a mixture of carbonic oxides and water vapour which carries in suspension soot or finely divided carbon to such an extent as to soil everything in its path and change the surrounding atmosphere to a grimy



BOILER ROOM OF THE CONSOLIDATED MILL OF THE AMERICAN STEEL & WIRE CO., AT CLEVELAND, OHIO
Showing the old hand-fired furnaces and the operating force. This plant has since been replaced by mechanical stokers

fog. The burning of anthracite does not cause smoke in this sense, while the semi-anthracites of Maryland and West Virginia produce it in such a mild form as to require only a high stack and a good draught for remedies.

As we go west into Pennsylvania, Ohio and Illinois, the decrease of fixed carbon in the coal and the increase of volatile matter present a new set of conditions.

The gradual heating of the fresh coal on the grate drives off the volatile hydro-carbons, which burn with a long, yellow flame. Any chilling of the flame or any lack of air for combustion immediately results in a separation of some of the carbon, which ceases to burn and is carried

along with the gases in minute particles.

The less perfect the combustion the more of this unburned carbon and the denser the smoke. The actual amount of carbon thus passing off even in the blackest smoke is small, rarely more than one-half of one per cent. of the coal burned on the grate, but its colouring power is enormous.

The small percentage of carbon thus wasted has furnished the conservatives a favourite argument against the economy of smoke prevention. It must be remembered in this connection that black smoke is an index of poor combustion, and that other ingredients besides carbon may be escaping unburned.

Furthermore, the rapid deposit of



AUTOMATIC STOKERS IN COURSE OF INSTALLATION AT THE CONSOLIDATED MILL OF THE AMERICAN STEEL & WIRE CO., CLEVELAND, OHIO

soot on the heating surfaces of the boiler decrease their conducting power in an alarming degree. A layer of soft coal soot is much more effective in checking the transfer of heat than an equal thickness of boiler scale.

The writer has conducted quite a number of tests on boiler plants before and after the installation of smoke-abating furnaces, and has known personally of many similar tests. The results have always been favourable to the new way, and the cleaner the chimney the larger was the rate of evaporation. It is not meant by this that all so-called smoke-preventing devices are economical. The most of them will not prevent smoke, much less will they save fuel.

It is urged by some that the usual efficiency test is not conclusive,

since the conditions are not normal. In some instances this is true, and the improved results are due as much to greater care in firing as to the merits of the furnace. When, however, the monthly coal bills for a year are decreased 10 or 15 per cent. by the adoption of mechanical stokers, the average manufacturer will not care to look further, but will accept the evidence. A personal letter from the manager of a refrigerating plant, where four mechanical stokers have been installed, says, in part:—"Our chief object in installing the stokers was to abate the smoke, and this they accomplish to such an extent that our chimneys are practically smokeless. In addition to this, we saved 500 tons of coal for the year."

Judging from the known size of the plant, this represents a saving of

about 10 per cent. of the total coal burned, and in dollars would correspond to a dividend of 15 or 20 per cent. on the cost of the stokers. Since smoke is caused by a lack of air or by a lowering of the temperature of the fire, it may be prevented by furnishing a supply of air adequate for combustion by mixing it thoroughly with the furnace gases and by maintaining a high temperature.

A careful fireman can realize these conditions by keeping a clean, bright fire, by putting on coal often and in small quantities, and by regulating carefully the supply of air both above and below the grate. To do this successfully he must have ample boiler and grate capacity, a good draught, and not too many furnaces to attend.

The expense for boilers and for labour will be greater than when the firing is done in the usual manner, but the saving of fuel will probably pay the difference.

The use of shaking grates, of automatic air supply over the fires and of suitable brick arches and walls will be of considerable assistance and reduce the labour cost. Where the water is reasonably pure the employment of water grates and a down-



AUTOMATIC SMOKE PREVENTER

Photograph of tall chimney one minute after firing

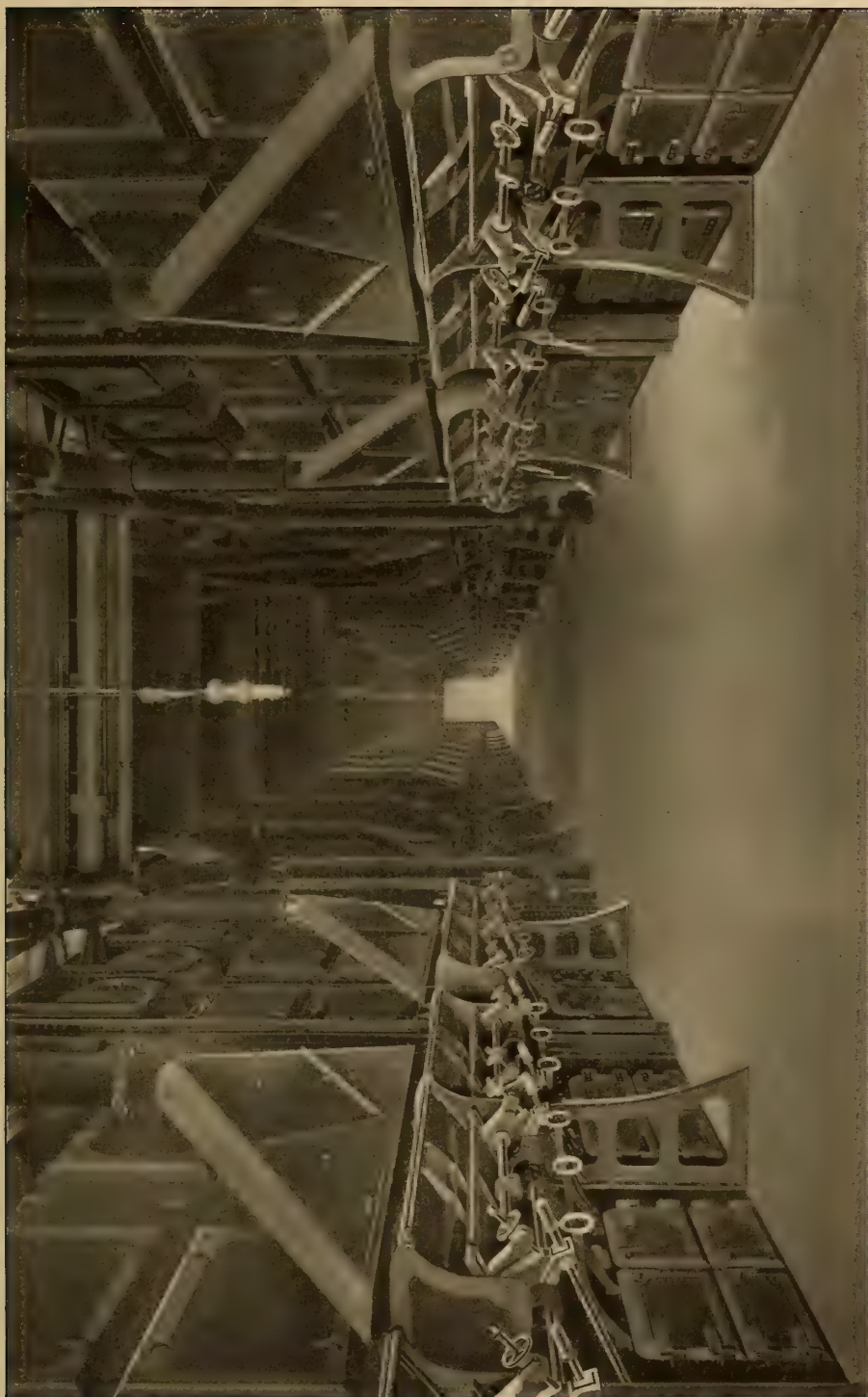
draught will be a good investment, increasing the heating capacity and reducing the smoke. With scale-forming water, any such complication is liable to increase the repair bill unreasonably.

Hand firing may be tolerated in small plants where but one or two boilers are used at a time and the coal consumption is small. In larger establishments it is uneconomical and unbusinesslike to do by hand what can be done better and more cheaply by machinery. One does not file and chip and scrape metal as of yore, because it does not pay to do so; the milling machine and the grinder have changed all that. It is just as foolish to handle materials in the old way with hoe and shovel when the machinery is at hand for doing these things. If there were no question of saving fuel or stopping smoke, the labour question alone would justify the introduction of mechanical handling in any large or medium-sized plant. A well-known mechanical engineer recently informed the writer of an instance where the force of firemen and coal passers was reduced from over forty men to four men as a result of the introduction of coal



AUTOMATIC SMOKE PREVENTER DEVICE ATTACHED TO FRONT OF BOILER

The supply of air is regulated to the demands of combustion



INTERBOROUGH RAPID TRANSIT COMPANY NEW YORK SHOWING 19,000 HORSE-POWER OF RONEY MECHANICAL STOKERS ON THE SECOND FLOOR OF THE BOILER PLANT,
AS INSTALLED BY THE WESTINGHOUSE MACHINE CO., PITTSBURG, PA.



MURPHY STOKERS AND ELECTRIC CRANE AT THE OTIS STEEL COMPANY, CLEVELAND, OHIO

and ash-handling machinery and chain grates.

If the coal is to be handled by elevators and traveling grates, the mechanical stoker must supplement them and take care of the fuel after it reaches the hoppers.

Furthermore, the mechanical stoker is undoubtedly to-day the best device for insuring good combustion and a clean chimney. It supplies the coal at a uniform rate, and introduces the air in such a way as to mix it thoroughly with the furnace gases and keep up a high temperature.

Those stokers which are in general use to-day and which may be regarded as having passed the experimental stage may be classified as follows:—

1. The inclined grates, as in the Murphy and Roney stokers.
2. The chain grates, like those made by the Babcock & Wilcox and Green Engineering companies.
3. The underfeed stokers, as typified

by the Jones and the American furnaces.

(1.) In the first class the coal is fed into a hopper, from which it is pushed on to a dead plate, where it cokes, and thence down an inclined grate. The grate bars form a sort of stairway with steps, which oscillate and jar the coal down. It burns gradually as it descends, and finally reaches the clearing or dumping grate at the bottom as ash and clinkers.

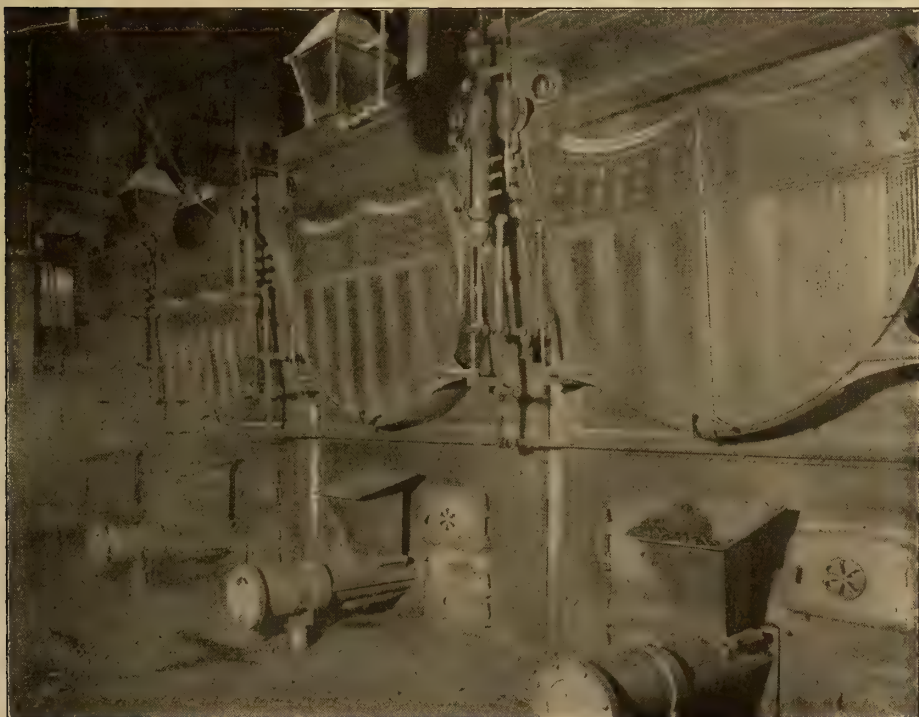
The grate may form one incline, sloping from the front to the bridge wall, as in the Roney furnace, or may consist of two inclines on either side of the boiler, meeting in a valley at the centre, as exemplified in the Murphy furnace.

These stokers have the reputation of being convenient and economical, and of preventing smoke when properly handled.

They have this disadvantage, that they are susceptible of being poked



AMERICAN UNDERFEED STOKERS AT THE DIVISION STREET PUMPING STATION, CLEVELAND, OHIO



JONES UNDERFEED STOKERS AS INSTALLED IN A CLEVELAND BREWERY

and sliced by hand in such a way as to cause imperfect combustion and a smoky fire.

If a fuel is used which melts and sticks to the grate bars, poking becomes necessary, green coal rolls down to the bottom, holes are made

handling to give the most economical results.

If the fire is too thin or the grate moves too slowly, there will be open spots at the rear end and too much cold air will pass through.

On the other hand, a thick fire or



CONSOLIDATED MILLS, AMERICAN STEEL & WIRE CO. OLD AND NEW PLANTS AT CLEVELAND, OHIO

Chain grates and ample chimney draft being installed for improved combustion and prevention of smoke

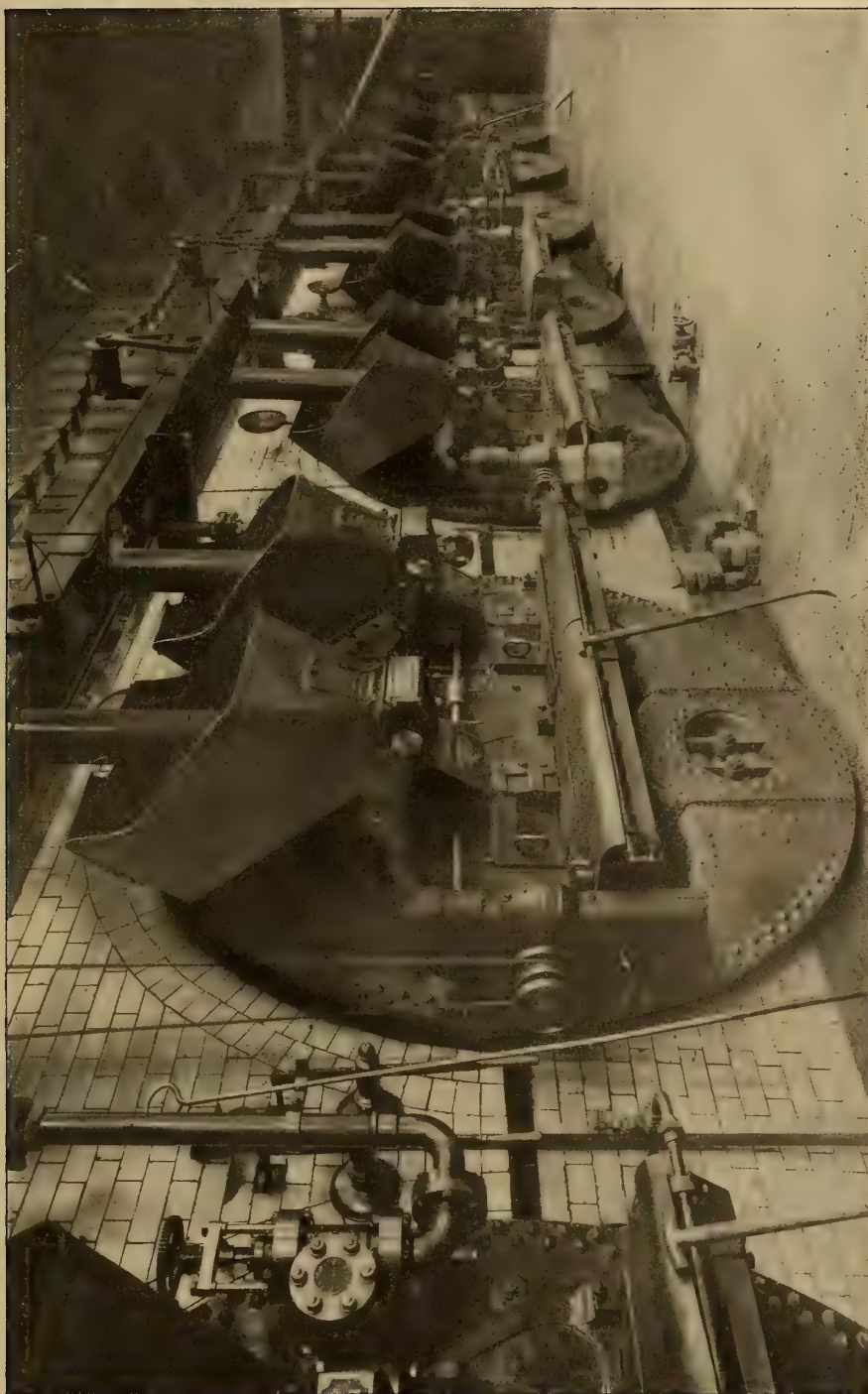
in the fire, and the combustion is irregular and uneven.

(2.) The chain grates are probably the best smoke preventers, since they give a smooth motion to the fuel and a uniform thickness, and require no hand service. The coal falls from the hopper on to an endless chain, travels slowly back, burning as it goes, and finally falls over the back end into the ash pit.

No hand cleaning is necessary, and hence there is no smoke, except at times of building a new fire. The chain grate, however, requires skillful

a quick travel will frequently cause partially burned fuel to be carried over the rear end and be wasted. With a reasonably uniform load and correct adjustment, these grates will give almost perfect combustion and entire freedom from black smoke. They have the further advantage that the ash is taken away automatically, and can readily be handled by mechanical carriers.

(3.) The underfeed stoker takes the coal from the hopper and pushes it under the grate by means of a plunger or a screw.



A VIEW OF THE BOILER-HOUSE OF MESSRS. MARTIN, SONS & CO., LTD., HUDDERSFIELD, ENGLAND, EQUIPPED WITH MECHANICAL STOKERS AND COAL-HANDLING PLANT BY MESSRS. ED. BENNIS & CO., LTD., BOLTON



AMERICAN STEEL AND WIRE MILL AT CLEVELAND, OHIO

Showing arrangement of chain grates and overhead electric crane for feeding the furnaces. A maximum efficiency with a minimum amount of labor

It rises thence through a rectangular opening in the centre of the grate and falls over to either side. Air is forced by a blower through tuyeres at the sides of the opening and up through the bed of coal, much as it does in a blacksmith's forge.

These furnaces will burn almost any kind of fuel and consume it completely. The air and the volatile matter from the fuel underneath must rise through the incandescent coal above, so that there is a thorough mixing of the gases and very complete burning.

The heat is intense, and the ash melts and forms a crust of clinker, which may be easily removed by hooks.

Good judgment must be used in regulating the speed of the coal-feeding mechanism, so as to preserve the right depth and area of fire, and in cleaning the fire properly.

Carelessness may result in serious injury to the furnace. The necessity of a forced draught, of course, entails additional expense and is a disadvantage.

One advantage possessed by this class of furnaces, and more particularly by the plunger type, is the ease with which the fire may be forced or relieved as the demand for steam varies.

In this respect the underfeed stoker is, if anything, superior to the hand-fired grate.

In criticising these prevailing types of mechanical stokers, the writer is relying partly upon his own experience, as all three are represented in his own boiler room. Each furnace has its own faults and its own excellencies, and each is vastly superior to the flat grate fired by hand.

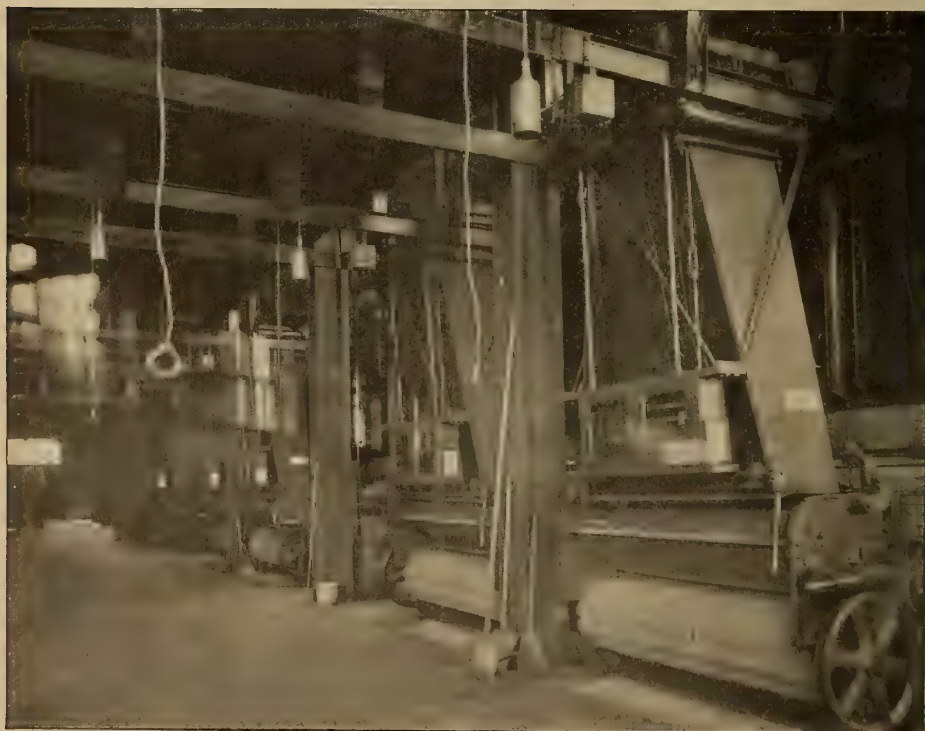
The chief engineer of a large corporation, having two of the most ex-



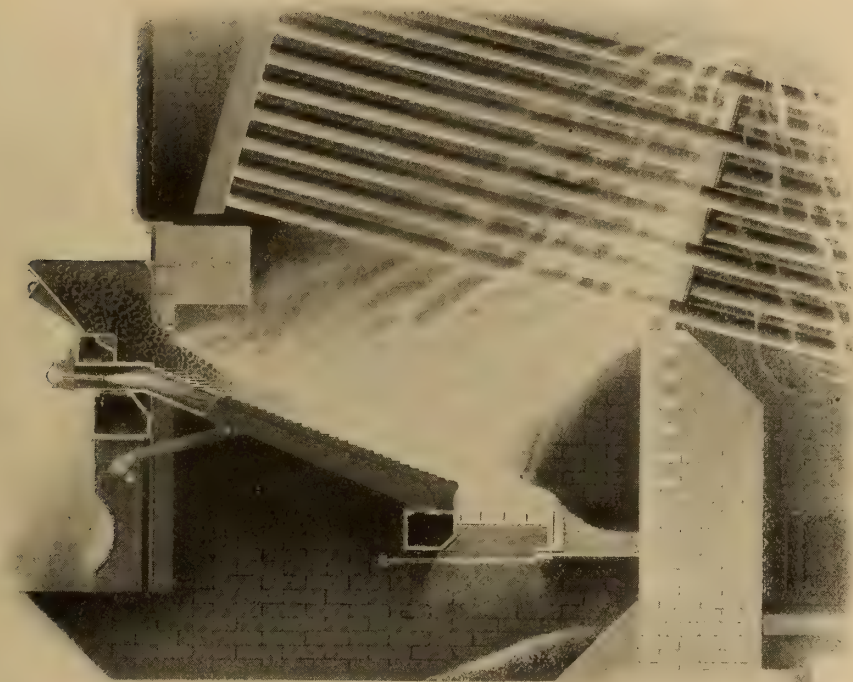
BABCOCK & WILCOX CHAIN-GRATE STOKERS IN THE BOILER ROOM OF THE COMMONWEALTH ELECTRIC COMPANY, CHICAGO



MURPHY STOKERS AND CHAIN GRATES IN THE BOILER ROOM OF THE CLEVELAND ELECTRIC RAILWAY COMPANY



CITY PUMPING STATION, CLEVELAND, OHIO. CHAIN GRATES, OVERHEAD COAL BINS AND WEIGHING CHUTES



WILKINSON AUTOMATIC STOKER AS APPLIED TO A WATER-TUBE BOILER

tensive and best equipped power houses in Cleveland, says in this connection:—

“While it is impossible for me to ignore the weakness in the above chain grate and mechanical stokers, yet I would certainly recommend the use of either of these stokers over hand firing in a plant of any size using bituminous coal.”

The president of a prominent tool manufacturing company in the same city writes concerning the chain grate:—

“We made a thorough investigation of the various devices on the market, and decided to equip our plant with the ——— chain stoker, and we have never regretted the choice. With a proper construction

of the combustion box the consumption of the fuel is so near perfection that the amount of black smoke issuing from the chimney is practically nil. If the plant is forced, there may be a little brown smoke at times, but it is never black. There is, in my opinion, no excuse for new steam plants being permitted by the municipal authorities to set their boilers without receiving a license or a permission from an officer that will have the proper power to insist upon some kind of mechanical device for stoking. There should be no black smoke issuing from stacks of manufacturing plants in a city, and I hope the time will soon be here when this will be a fact and not a dream.”

In the refrigerating plant before

referred to the remarkable saving in fuel noted was accomplished by the use of underfeed stokers.

In regard to inclined grate stokers, the manager of one of the largest office buildings in Cleveland writes:—

"We have installed here three 200-H. P. ——— stokers. They have been in constant use over four years and burning slack coal. We have had no repairs to the boilers, outside of replacing the brick lining, and this has been at a cost of about \$50 per boiler, or \$150 for the four years. The smoke is practically consumed, and, as shown by reports of city smoke inspector, the unconsumed smoke is less than one per cent. Our equipment is economical in consumption of coal."

Fortunately for the general public, smoke abatement is not merely

a question of right and wrong, but also a question of profit and loss.

If ethical considerations alone were involved, it is to be feared that the average corporation would continue in its evil ways, but when it becomes a matter of actual demonstration and of everyday experience that smoke abatement is profitable the problem will solve itself in time.

The illustrations in this article show some of the stoker equipments in power plants in Cleveland, Chicago, New York and elsewhere. The efficiency and economy of mechanical stoking has been so well established that few manufacturers or business men at the present time would think of installing a plant of any considerable size, in factory or in office building, without some mechanical method of firing the coal.



THE FIELD OF ELECTRIC ALTERNATING-CURRENT SERVICE

By H. S. Knowlton

THE relative advantages of the direct and the alternating electric current is an interesting subject for inquiry at the present time. In the April issue of last year Mr. H. L. Abbott discussed the field of direct-current service, and in the following number Mr. Alton D. Adams examined especially the claims of the direct current as an advantageous system for the long-distance transmission of power. In the January number of this magazine there appeared the fully illustrated paper of Mr. C. T. Wilkinson, giving a description of the successful installations of the Thury system in various parts of Europe, over distances up to 180 kilometres, at pressures as high as 60,000 volts. For the sake of completeness, the writer desires to place in comparison with the direct current the special field of usefulness of alternating-current service, with particular reference to the use of the single-phase electric motor.

Whatever else may be said of alternating-current practice, there is little doubt that it will constitute the backbone of long-distance transmission for many years to come. Direct-current transmission at high voltages may be reasonably successful as long as the amount of power conveyed from point to point is small; but at present, at any rate, there is small hope of building continuous-current, high-voltage dynamos in capacities comparable with the large alternators which are being so successfully operated in all parts of the world.

A great deal has been said of late about the feasibility of transmitting power several hundred miles by di-

rect current at high voltage. In considering such a project one must remember that it is a very difficult problem to design and build a successful high-voltage commutator capable of carrying, say, ten or twenty times the amperage of an arc light machine of the constant-current type,—the only thoroughly successful high-voltage, direct-current generator in extensive service to-day.

The ease with which an alternating current can be transformed in voltage and quantity is a matter of universal knowledge. Familiar as this characteristic is it is still the corner-stone of the alternating-current fabric. Desirable as it is to avoid transformer losses in a power system, the fact remains that without the transformer the flexibility of alternating current would become a by-word. Then, too, in very large sizes the efficiency of the transformer comes within one or two per cent. of absolute perfection, and the transformer plant pure and simple requires only nominal attendance, except in the case of great railway or power sub-stations, where a service interruption means a loss of much money to the consumer and to the producer.

A densely populated district can be served by direct current locally with the utmost advantage, and if a power plant be located near the distribution centre of such a district there is little reason for a change to alternating-current methods. But if the district to be served is sparsely settled or if in supplying the thickly-settled region from a distant power plant, it is necessary to traverse long stretches of comparatively unsettled

country, the alternating current often becomes an absolute necessity if the community is to have any service whatever.

It can, therefore, be laid down as a general truth that the present alternating-current field is in suburban or sparsely settled districts. Many of the smaller central stations are now changing over their entire equipment for alternating-current service. It is, naturally, a matter of considerable expense to do this, and it is a question how far such a policy is wise, considering the investments in direct-current machinery in the large cities. The policy of generating and selling alternating current alone is doubtless a good one in a community which can expand on the alternating-current basis; but it is not reasonable to expect very large cities to undo previous practice in this way. A purely alternating station and distribution system is a wonderfully simple operating proposition, and there is little doubt that in looking ahead a series of years the alternating layout gives the greatest assurance of meeting future conditions on account of its superior flexibility.

With the exception of variable-speed machine-tool driving, electrolytic and storage battery work, the alternating-current system gives essentially as good service as the direct current. Suburban populations are growing rapidly everywhere, and the central station man who cannot offer scattered consumers alternating current for domestic use in lighting or small power work is losing an excellent opportunity to build up his business. The whole problem of suburban residence lighting depends upon the alternating-current transformer. Distribution at one or two thousand volts is absolutely necessary for commercial success, unless it be in very small suburbs which are served by local generating plants,—and usually such small plants are not noted for their operating economy.

Until within two or three years alternating-current distribution for

power service, has been sorely held back by the lack of a suitable variable-speed, single-phase motor. The constant-speed induction motor for two or three-phase circuits has served its purpose admirably in situations where the business warranted the extension of polyphase circuits from the central station. It is true that a given amount of power can be transmitted for the same loss over a three-phase circuit with 25 per cent. less copper cost than with either single or two-phase lines; but copper cost is not the only item to be considered in such a case. A two-wire system is only 67 per cent. as likely to break down as is a three-wire system; the cost of special construction at corners, etc., is much less with the former; the early lighting customers can be supplied sooner with power, for in reaching out for new business the pioneer lines are almost invariably single-phase; the insulation and erection cost is less, and there is a notable saving in the cost of transformers.

The single-phase motor at present costs a good deal more than the polyphase or the direct-current machine of the same rated capacity, but designs on the market admit a fair measure of variable-speed control, and also offer the central station a distributing simplicity that is exceedingly advantageous. Combined with cone pulleys and gearing adjustments there is no doubt that many suburban factories and machine shops can now be equipped with single-phase alternating motors capable of meeting all the demands for speed variation which are likely to occur in regular commercial service.

The problem of circuit balancing is simpler in the case of induction polyphase motors, and the lower first cost of the motor itself is naturally a strong point in favour of the older type, in cases where polyphase lines are available and where constant speed is satisfactory to the consumers. It is not the purpose of these

comments to discuss at length the technical points for or against single-phase and induction polyphase motors, but to point out the fact that the development of the single-phase machine has been an important feature of alternating-current extension in many central station territories.

Small single-phase motors,—up to 5 H. P. certainly,—are in many cases being installed on lighting circuits by consumers without special notice to central stations, and carefully planned installations with motors as large as 40 H. P. are coming into wider service on single-phase lighting mains. The alternating-current motor, either single or polyphase, does not, as a rule, give better service under ordinary conditions than the direct-current machines turned out by the better class of manufacturers, but the point in suburban or even rural work is that it costs too much to bring direct current to the isolated consumer to make it profitable to connect him into the system. Nothing has surpassed the induction motor in the matter of withstanding very severe conditions.

The alternating-current transformer sub-station is seldom objectionable, even in a suburban residence district, for it need contain no revolving machinery capable of making a perceptible noise. When such a building is designed with an eye to architectural effect it may easily become an attractive addition to the locality which it serves.

The first cost and operating expense of a transformer sub-station must inevitably be less than that of a direct-current station of the same capacity. By carrying out the high-voltage principle upon distributing lines fewer sub-stations are required in a given territory. Transformer core and copper losses can be eliminated in many installations by putting oil switches in the primary leads, especially in factory plants. The smaller lighting transformers can readily be treated in the same way.

This point was touched upon in the April article, already mentioned, and it is quite important in a large distributing system.

The charge has been frequently made that a storage battery cannot be used upon an alternating system to take care of load peaks unless an expensive rotary converter or motor-generator set is installed to change the current as conditions demand. This is, of course, true; but first cost is by no means the final and only consideration in any problem of engineering finance. In fact, it is almost always the case in modern industrial operations that the introduction of labour-saving appliances or more economical machinery is a matter of considerable expense. But if it can be shown that the purchase of an appliance will effect a saving in the long run sufficient to offset the fixed charges, it does not so much matter just what the first cost is. The fitting of the storage battery to purely alternating service is still in a stage of development, but there is no reason why a combination of motors and generators cannot be effected on a single base which will meet the most variable conditions of supply and demand between an alternating-current distribution system and a regulating battery plant.

Operating at the same voltage cable conductors for alternating-current service are superior to direct current, as regards safety and durability, for the reason, theoretically, that with the former there is no electrolytic action tending to break down the insulation. Oscillations are capable of causing much trouble in alternating systems but these can be minimized with careful design and lightning arrester protection. The absence of lurking defects in high-tension cables and the small currents transmitted mean less possibility of breakdown and less chance of disturbance to telephone circuits than is the case with low-tension direct-current service. Aside from the difference in first cost the weight and space of

transformer plants is considerably less than that of direct-current machine installations.

The alternating-current arc lamp has in late years been perfected to a degree which enables it to be substituted for the direct-current lamp with satisfaction in many classes of service. The Nernst lamp is essentially an alternating lamp at present, and other new high-efficiency lighting units are quite as suited to alternating service as to direct current. The magnetite arc lamp is essentially a direct-current device, but it can be used on an alternating system in connection with a mercury arc rectifier.

Most electric heating devices can be operated equally well upon either current, but in heavy electric furnace work the alternating current is of prime importance on account of the absence of electrolytic effects and the ease with which currents of enormous amperage and low potential can be obtained by transformation. On any alternating distribution system where direct current is needed for automobile charging, arc soldering, and lamp projecting it is a simple matter to install a motor-generator or small rotary converter and obtain the desired quality of current from the alternating mains with a minimum of complicated apparatus.





Current Topics

ONE of the urgently pressing matters in connection with manufacturing and engineering industries appears in the need for some method of providing competent workmen. The old apprenticeship system is practically a thing of the past, and it is to be questioned whether it would really be able to cope with the situation, even if conducted with full energy and vigor along the old lines. Shop methods have changed, and the whole art of working metals and other materials of construction is in the course of a transformation, a revolution which necessarily includes the men as well as the tools.

The question has been before the world for a number of years, but its importance has grown rapidly within the past few years. In various papers presented before the American Society of Mechanical Engineers the matter has been discussed, notably by Mr. Horace See in his presidential address; by Mr. Milton P. Higgins, well known for his work at the Worcester Polytechnic Institute, and more recently by Mr. Magnus W. Alexander in connection with the work of the General Electric Company.

It is not our intention here to discuss the various plans which have been proposed to provide skilled workmen in the different mechanical industries, but rather to emphasize the changed conditions under which shop work is done to-day over those obtaining in the time when the apprenticeship system was developed, and also to sound a note of caution against the advocacy of any system which does not take into account the extent to which those conditions may continue to change.

Formerly the skill of the workman was measured by his ability to perform by manual methods operations now accomplished far better and more rapidly by machines more or less automatic in operation. The use of the hand lathe was at one time the criterion of ability in the shop, and the man who could cut a true thread with a chasing tool felt that his status as a mechanic was unquestioned. Accurate filing and chipping formed an essential portion of the education of the apprentice, but to-day they bear much the same relation to the work of the machinist as a beautiful handwriting does to the equipment of a stenographer in these days of typewriting machines. It is

needless to multiply examples. That there will always be a limited demand for a high grade of manual skill in the machine shop will be freely admitted, but such work is being more and more eliminated from commercial manufacturing operations, and relegated to the tool room, the experimental department, and the model shop, and in its place there is demanded an altogether different kind of ability.

Under modern methods of machine-shop operation, continual operations of instruction have been found necessary in the shop in connection with the actual conduct of the work. The methods of handling work are not left to the general judgment of the workman, but are determined by the administration in the light of the nature of the work, the materials by which and upon which the work is done, and the permissible costs involved. Under such supervision, the workman is instructed for the particular job under consideration, so that his daily work forms, or should form, a continual educational course for him, advancing with the state of the art and with the progress of the tools with which his work must be done.

The proper foundation for such shop work cannot be found in the old apprenticeship system or in anything based upon its methods. Those methods involved in their very essence the slavish imitation by the apprentice of the processes which he saw going on about him. These processes, many of them at the time in the course of supersession, had to him little or no connection with the fundamental mechanical principles involved, but were to be followed blindly without question or hesitation, his one aim being to be able to do what he observed as well as the man he saw doing it. The method was all right during the years in which shop routine remained practically unchanged, but it will not do for to-day, much less for to-morrow. The competent workman must know enough

of the actual principles involved in his work to be able to understand the reasons for doing as he is told. He must know the necessity for getting the maximum output from a machine before its career as a modern tool is terminated by the appearance of its more efficient successor; he must consider all his work as a means to an end, both for himself and for his employer; in short, he must become a thoughtful and interested element in a whole system of productiveness, and not a routine imitator of past methods, methods continually slipping farther and farther away into the limbo of ancient mechanical history.

THE development of the hydraulic power of Niagara on the Canadian side is leading to some interesting sequences, both in connection with questions of public and private control, and also with the matter of the export of electrical energy from the Dominion to the United States.

As a consequence of recent legislation a tribunal called the Hydro-Electric Power Commission has been created, and into the hands of this body has been placed the entire domestic regulation of the power product of stations coming within Government control.

In addition to the creation of this commission, there has been given to the various municipalities the right to undertake the distribution of electrical energy within their respective limits, so that private companies find themselves required both to compete with municipalities, and to submit to official regulation of their tariff charges.

In order that this commission may be in a position to dictate terms to the existing private companies it is important that the co-operation of the municipalities be obtained, and this appears to be already partially accomplished. The city of Toronto has already arranged for 15,000 H. P.

of electric energy from Niagara, the price being \$14 to \$16 per horsepower for a supply for a twenty-four-hour day, including transmission to Toronto, the local distribution to be in the hands of the municipality, and it is believed that a number of other cities and towns will make similar arrangements. These agreements are made with the Hydro-Electric Power Commission, and it in turn must either secure the power supply from the existing private companies or else proceed to develop its own stations. It is hardly probable that the latter alternative will be found necessary, since the result would be to leave the private corporations with the greater part of their prospective custom permanently taken away, so that the real consequence of the recent legislation is to compel the companies to supply the municipalities through the commission at prices determined by the engineers of the new body.

It is possible that such measures will prove advantageous to the public, but much will depend upon the manner in which the law is carried out. If prices are so arranged as to afford the power companies a fair margin of profit and at the same time offer sufficient inducement to manufacturing enterprises to expand in the districts thus supplied, the Dominion as a whole should be greatly benefited by the plan. It is entirely safe to state, however, that if this plan had been publicly announced before the present great power development works were begun, it would have been found vastly more difficult to raise the necessary capital than was the case before Government control appeared upon the scene. It has been intimated that this legislation will render it exceedingly difficult for promoters to induce outside capital to engage in the development of natural resources in Canada hereafter, so that probably future enterprises will be more difficult of exploitation than has been the case with these existing power plants.

IN the spring of last year there was issued by the Minister of Commerce of the French Government a circular letter to the presidents of the Chambers of Commerce in various cities of France, urging them to co-operate with him for the effective suppression of the illegal use of the old denominations of weights and measures. This circular, which was published at the time in several papers in Great Britain and America, revealed the fact that the old denominations, such as *livre*, *boisseau*, *pie*, *arpent*, etc., were in far more extended use than had been admitted by the advocates of the metric system in England and the United States. Although the law of July 4, 1837, by which the metric system was made compulsory in France, provided severe penalties for infractions of its provisions, it was not deemed expedient to enforce the penalties too rigorously, and the Minister of Commerce therefore endeavored to discover some milder method of suasion to effect the complete suppression of the old denominations.

The presidents of the Chambers of Commerce, however, do not appear to have shown much enthusiasm in this thankless undertaking, and, having in mind the convenience of the members of their associations rather than the rigid enforcement of an inconvenient law, they are by no means unanimous in complying with the official request. According to some comments upon the situation in "*Le Petit Journal*," the president of the Chamber of Commerce of Paris is one of the dubious ones, his reasons for hesitating to insert the ministerial circular in his "*Bulletin*" being as follows:

By forbidding the use of the old denominations of weights and measures, the habits of buyers and sellers will be upset and the course of trade inconvenienced. Those who sell by retail say that the bushel and pound are in such continual use that they do not wish to inconvenience their cus-

tomers by selling in litres and grammes. The change is the less necessary since the pound has a definite value in grammes and the bushel in litres. Sellers of wines and other drinks assert that they cannot prevent their customers from asking for chopines and setiers, which are supplied in measure of legal capacity, the chopine and setier corresponding to a half litre, and the half-setier to a quarter litre.

Land surveyors state that they are compelled, in order to make their accounts intelligible to their clients, to give the values of hectares, ares, and centiares, in perches, arpents, and feet, according to the customs in the different provinces.

All these examples serve to show the extreme difficulty in uprooting terms and values so closely connected with the past as are the weights and measures of a people. This is especially true of linear units, with which, in most instances, the working dimensions of daily use are involved, and which are so closely tied to the past as to be almost incapable of change.

The activity among the advocates of compulsory metric legislation appears to have been shifted from the United States to Great Britain at the present time. With the failure of the committee of the House of Representatives to report any metric bill to the present Congress, one of the most persistent attacks upon the existing system of weights and measures in the United States has been checked, and this mainly by the opposition of the engineering and manufacturing industries most nearly concerned in the matter.

In Great Britain the efforts of the metric advocates appear to be in much the same aggressive position as they were in America last year, but it is believed that when the engineering community is fully aroused to the real meaning of any compulsory legislation upon the subject

the attack will be repulsed at Westminster as effectively as it was at Washington. Both in England and in America the metric system has long been made legally permissible, and its failure to make any definite progress under such favorable conditions should be sufficient evidence as to the degree to which it is unacceptable to the public.

THE question of the development of the hydraulic power of the Victoria Falls, of the Zambesi, and its electrical transmission to the Rand, is still a matter of interested discussion. The plan involves the construction of a line 600 miles in length, capable of delivering 30,000 horse-power, but the details are not definitely settled. If, as is proposed, three-phase current at 150,000 volts is used, the problems of handling such a current at such a pressure will exceed anything which has yet been attempted. It is proposed to use aluminum for the line, the conductors being placed at the angles of a 14-foot equilateral triangle, the supports being steel towers 60 feet high. These plans may yet be modified, and it has been suggested that the Thury direct current may be employed, according to the general system described by Mr. Wilkinson, in his article in our last issue.

It has not yet been determined whether the electrically-transmitted power can compete commercially with steam-driven generating stations nearer the point of utilization; but at least one element, the steam power plant, appears to be in a position to demonstrate its efficiency before long, as a steam power station is to be erected at Vereeniging, about thirty-five miles from Johannesburg, where both coal and water are available, leaving the development of the long-distance plans and the Zambesi hydro-electric station to be worked out hereafter.



From Other Points of View

The Victoria Falls Power Scheme

Sir Alexander Kennedy, "Engineering"

THE total horse-power in the mines on the Rand is officially given as about 230,000. Of this, however, about half is used in mines whose probable life does not exceed fifteen years, and may, therefore, be left out of account. Of the remainder, about 25 per cent. is used at present in the form of compressed air at the faces, where it is unlikely that the electric will supersede the pneumatic system; of what is left, something like 12,000 horse-power is already electrical, so that the total possible future market in the Rand, so far as can be seen, is about 75,000 horse-power. Considering the large capital expenditure required for electrification, and the varying views of mining engineers as to the extent to which it is feasible to use electricity in the mines, it will be seen that a total of 50,000 horse-power represents a somewhat sanguine estimate, and that the preliminary amount of 20,000 horse-power, now being spoken of as a small first instalment, really represents a fairly large proportion of the possible demand.

The Victoria Falls scheme is to start with the erection on the Rand of an ordinary steam station on mod-

ern lines, containing about 20,000 horse-power in boilers, steam turbines, and dynamos. This, of course, would be in itself a reasonable and proper scheme if it is not to be grossly over-capitalized. But although it may be shrewdly suspected that this station, if it were ever constructed, would be the end as well as the beginning of the enterprise, I am bound to assume, at least on paper, that the scheme for which the public is to find money is something enormously greater.

First of all, then, comes an ordinary 20,000 horse-power steam station. Next a huge low-level reservoir with electrically-driven pumps, to utilize a part of the power coming from the Falls for pumping water into a second reservoir 600 feet above the first. Then pipe-lines coming down again connected to separate turbine-driven electrical plant, again of 20,000 horse-power, so that at this stage we have 40,000 horse-power of dynamos, 20,000 horse-power of steam plant and the same of turbines, and 6000 horse-power (more or less) of electric motors and pumps; two reservoirs, each of about 20 million gallons capacity, with their dams, etc., and two high-pressure pipe-lines, all for a gross delivery of 20,000 horse-power to the mines.

The reservoirs are to be large

enough to contain water for driving the 20,000 horse-power turbine plant for twelve hours continuously in case of breakdown.

Then, in addition to the plant which I have mentioned, the complete scheme provides that each 20,000 horse-power at the Rand must have (a) about 30,000 horse-power of turbines, dynamos, and transformers at the Falls; (b) 700 miles of high-tension transmission line, and (c) 20,000 horse-power of transformers, etc., at the Rand. It strikes one as rather "a large order" to have to provide about 70,000 horse-power of dynamos alone and 50,000 horse-power of turbines, not to mention the 700 miles of transmission line, the steam-engines, reservoirs, pumps, pipe-lines, and so on, for the sake of 20,000 horse-power on the Rand itself.

And it must be noticed that this is not only just at the start, for the power of the steam station, the power of the turbine plant, and the 12-hour capacity of the reservoirs must always be kept equal to the capacity of the transmission from the Falls. When the latter, therefore, comes to 50,000 horse-power, there must be a 50,000 horse-power steam station, reservoirs to supply 50,000 horse-power for 12 hours, a turbine-driven plant also of 50,000 horse-power, and so on. I can hardly imagine that the effect of this triple system upon the capital cost, and therefore upon the capital charges, has been seriously considered by the promoters, but I trust the public will consider it very seriously indeed.

As a matter of comparison, and as showing what the real financial magnitude of the business is on a proper commercial scale, it is interesting to notice how the Rand Central Electric Works, who are not asking the public for any capital, are situated now that they are extending their plant on modern lines, with the intention of supplying cheap power on a large scale. They possess an ex-

cellent site near the coal fields, where they are now obtaining coal under 10s. a ton; they have a 12,000-volt transmission line already erected along the Rand; they have long ago obtained full power to supply the mines wherever current is required, and they also have acquired the right to put up a new transmission line along the Rand, at 50,000 volts, for power purposes. The total cost of extending the Rand company's present plant by an amount of 20,000 horse-power, and putting down the corresponding transmission lines along the Rand, is estimated at under £400,000, and tenders for the first section of the plant are at present under consideration. The total cost of this plant will, therefore, be about £20 per horse-power, and the whole capital charges upon it, allowing for interest at 6 per cent., and for ample depreciation, will not exceed 0.16d. per unit sold to the mines.

The total cost of the Victoria Falls system cannot be less than £100 per horse-power. The capital charges alone on this will amount to about 0.80d. per unit. As power must be sold for something under 1d. per unit, it is obvious that practically the whole price is swallowed up in capital charges, before anything whatever is put down for working, maintenance and management, including the "proper patrolling" of 700 miles of veldt, and the "sufficient number of breakdown gangs."

I do not wish to take up your space with any discussion of technical details, although on such points there is much to be said which differs from the statements which have lately been going the round of the papers. But I write this in the hope that an engineer's view of the hopeless finance of the scheme, apart altogether from its special engineering difficulties, and possibly fallacies, may, perhaps, prove a useful counteractive to the fascination which anything sufficiently big and sufficiently distant seems to exercise on the public.

The Manufacturing Cost of Alcohol

Albert P. Sy, "Journal of the Franklin Institute"

WITH reference to the cost of the production of grain alcohol, the following points were brought out before the committee of Congress, the data being obtained from the books of a large distillery in Peoria, Ill:—

The average price paid for corn for ten years was 42.36 cents per bushel; the average amount of alcohol from a bushel of corn was 4.76 proof gallons (50 per cent.); the average cost of a proof gallon was 10.78 cents. The cost of corn for one proof gallon was 8.89 cents; subtracting this 8.89 from the total cost, 10.78, there is left 1.89 cents as the cost of making one proof gallon of alcohol. At this rate it would cost 3.4 cents per gallon to make 90 per cent. alcohol, or a total cost of 19.4 cents per gallon, including the corn. Lately the methods for producing alcohol have been improved so that about 5 proof gallons can be made from one bushel of corn, or the total cost of a gallon of 90 per cent. alcohol is 18.4 cents.

With reference to the amount of alcohol that may be produced from corn and potatoes, Secretary Wilson, of the Department of Agriculture, said that one acre will produce (average) 50 bushels of corn, from which there can be made 882 pounds of absolute alcohol, or about 130 gallons, which corresponds to about 140 gallons of 95 per cent. alcohol. One acre will produce 18,000 pounds of potatoes, from which 1620 pounds of absolute alcohol, or 255 gallons of 95 per cent. alcohol, can be made.

Before the same committee a representative of farmers' organizations said that with corn at 30 cents a bushel, yielding 2.5 gallons of 95 per cent. alcohol, the total cost of making one gallon would be about 12 cents a gallon, and could be sold for 20 cents a gallon.

An enormous amount of starchy material goes to waste annually in

the stalks of the corn, i. e., in the plant itself, which in most cases is not removed from the land. With commercially practical methods for recovering and utilizing this waste, the production of alcohol per acre of corn can be greatly increased. The Department of Agriculture has been making experiments, using corn cobs and stalks for making alcohol; it is believed that this will develop into an industry of considerable commercial importance. These materials have heretofore been allowed to go to waste. Experiments made at Hoopston, Ill., in the corn district of that State, have shown that sufficient alcohol can be recovered from these raw materials to justify the erection of a distilling plant. According to reports, eleven gallons of alcohol have been obtained from a ton of green cobs, while a ton of green stalks yielded six gallons.

Another important source of alcohol is the low grades of molasses, those grades that cannot be sold as molasses. In Central and Southern America and the West Indies there are produced annually millions of gallons of low-grade molasses, which at present are burned, destroyed or fed to animals; a small proportion is brought to the United States to be worked up into liquors. While this material is much cheaper than corn as a source of alcohol, it produces an alcohol which is unfit for making beverages on account of the odour and taste which it derives from the molasses. But for industrial purposes where this alcohol can be used tax-free this odour and taste are no objections. On account of its cheapness, this molasses is considered by some as the most important source of alcohol at present not developed.

In Cuba alcohol is now made from this molasses at a cost of 10 cents per gallon, according to a report of United States Minister Squires. In the United States this molasses can be bought for 3 cents per gallon, and it takes about two gallons to make a gallon of alcohol; with a cost of

3.4 cents per gallon for making, 90 per cent. alcohol from this source would cost 9.4 cents to produce.

Another source of alcohol is the low-grade molasses produced in the manufacture of sugar from beets. Ten factories in the State of Michigan produced enough of this molasses which was converted into 1,000,000 proof gallons of alcohol in a distillery in that State. While at present the beet sugar industry is still in its infancy, it is obvious that with its development this will furnish a by-product of importance in the alcohol industry.

Minor Faults of Machine Design

From "Engineering"

THERE are few things more profitable to the engineer than a careful and conscientious examination of the design of a machine, with a view to its improvements in details. Every wide-awake manufacturer may fairly be credited with having a general knowledge of what his competitors are doing, and is probably satisfied that he is well abreast of current practice. He takes every opportunity of inspecting the machinery of his rivals, and spares no pains to make himself acquainted with their most recent improvements. This is quite right and proper; but there is a most fruitful field for investigation nearer at hand, which is often apt to be neglected. Is the manufacturer sure that his own machinery is as perfect in design as care and experience can make it? Does it form the best compromise that can be obtained between efficiency, reliability, ease of manipulation, and cheapness of manufacture? We may assume that any of his standard machines has no very serious faults in its general design. It sells well, and gives satisfaction to the purchasers, while leaving a reasonable profit to himself. He will naturally be content to let well alone, believing that any improvement which could be made would be so slight as not to

be worth the trouble and expense of altering his standard practice. But let him look into the matter a little more closely. Granted that the machine does its work satisfactorily, and that the general design is in no need of revision, are the details all as they should be? Let him go over the design detail by detail, seeking reasons why this should not be made much lighter, that abolished altogether, and the other modified so as to reduce its cost of manufacture.

When a manufacturer, by a course of criticism such as we have mentioned, has discovered perhaps a dozen minor points in which the design of one of his productions might be materially improved or cheapened, his first impulse is to blame the head draughtsman for having allowed such details to escape his notice. Such a course is not entirely fair. The head draughtsman is a busy man, and his time is fully occupied by matters of much greater importance than the supervision of every mechanical detail on a drawing. Only such points as catch his eye in glancing over a general design can he be reasonably expected to correct, and most of the minor faults will be in connection with details which he has trusted to subordinates. The origin of minor faults undoubtedly lies with the junior draughtsmen, and, once committed, their perpetuation is almost guaranteed by the fear of departing from "our practice." They are copied from one design to another until their antiquity renders them almost sacred. Possibly, in the first place, there was some valid reason for a certain practice, which has long since vanished; but in most cases an error will have been an error from first to last. A periodical critical examination of designs will weed out the features inherited from an obsolete practice and will prevent the continuance of such recent faults as have crept into the drawings.

A thorough familiarity with workshop processes,—not the superficial acquaintance with their principles as

taught in a school, but that knowledge only to be learnt through the fingers by practical work,—is the best antidote to bad designing. Half that which goes by the name of the science of engineering is never needed once in a lifetime by a draughtsman, while the instinctive tendency to make a casting, say, in the easiest form for moulding, machining, or erecting, is wanted every day and all day long. A man practically familiar with machining, for example, could never design an article which would require two or three settings in the lathe, or on the planer, when one would suffice; and a competent erector could never forget that pieces of machinery have to be lifted, and often get roughly handled. The fact is, that the profit or loss on a contract is very largely indeed determined by the time the working drawings leave the office, and the attention paid to the design of details makes the finished machine a standing credit or reproach to its makers as long as it shall last.

Distribution of Power from Blast Furnace Gases

F. E. Junge, in "Power"

THE surplus power which remains available after deducting all requirements within a works may be utilized in various ways. The most feasible and the one most often used is to deliver light and power to communities or cities located in the immediate vicinity of the plant. Where these natural outlets are not available, it is becoming more and more customary to establish a system of power exchange between such works as are located within a certain commercial distribution sphere relatively to each other, the object being to save in initial and operating cost of plants, to balance the stability of output by a corresponding provision for consumption; in other words, to obtain a constant high-load factor for the com-

bination of works, and last, but not least, to provide for a common and ample source of energy in cases of emergency.

Thus small coal mines which produce good coal for coking purposes, and have sufficient coking capacity, will install a coke-oven gas power plant which, besides furnishing energy to these mines, distributes electric power in the form of high-tension electric current to neighbouring mines at a profit, or they will make an agreement with some central electric station to deliver a certain amount of energy at a certain figure all the year round to the said station, whence it will be sold and distributed to consumers at a profit. Since the central station holds similar contracts with a number of individual contributors, and since the agreement provides that in case of a break-down any contributor may become a consumer, that is, may take energy for emergency uses within his works from the line, it is evident that this arrangement offers an ideal means of making and selling energy under economic conditions profitable to all alike over wide territories, provided that the respective concerns can persuade themselves that a combination of such mutually beneficial character does not preclude competition.

The saving effected through these combinations is due, on the one hand, to the elimination of special power generating units and costly reserves; on the other, to the maintenance of a constant high load factor. The importance of the latter item will be appreciated when it is considered that in some gas power plants an increase of the load factor from 25 to 50 per cent. will halve the total cost of power.

For the practical realization of reciprocal policy we must again turn to Germany, where, owing to the close concentration of industrial centres, most headway has been made in the centralization of power. In a recent paper on the production and utilization of power in metallurgical

and mining pursuits, Dr. Hoffman, of Bochum, discusses quite a number of such combinations, of which the one covering part of the territory of Rhenish Westphalia is the most interesting, because it is the largest of its kind up to this date.

The price paid by the Rhenish-Westphalian Electric Central Station to the various iron smelting plants and collieries for their surplus energy is 0.7 cent per kilowatt-hour. Owing to its own large power plants, aggregating about 55,000 horsepower, and to the fact that it can save the reserves, it is possible to sell energy at a very low rate.

For instance, to large consumers, such as factories, rolling mills, collieries, etc., the charge is 1.4 cents per kilowatt-hour, and for driving motors which run at a constant high load factor, such as fans for mine ventilation, the charge is as low as one cent. This central station has also made contracts with several communities and cities, and has taken active part in the operation of smaller central stations and of electric railroads running through the commercial distribution sphere of their works. The tariff rates are based on a sliding scale, beginning at 7.6 per kilowatt-hour for light, and 3.5 cents for power, and decreasing in proportion to the consumption to 3.5 and 1.4 cents, respectively.

Refrigeration and Power Production

"Electrical World"

THE fact that mechanical refrigeration is sometimes produced in large power plants as a by-product resulting from certain limitations in the utilization of the power, is well known to most engineers. The extent to which this process is an efficient one and the possibilities of its further extension are not as commonly known. In fact, the reasons by which mechan-

ical refrigeration becomes practical and desirable under these circumstances and the extent to which these reasons operate are still more unfamiliar. The problem of power production is generally treated by engineers familiar with this work only, and the limitations of refrigeration and its possible future development, with the resulting influence on this work, is practically unknown.

That refrigeration is an extremely convenient and efficient method of utilizing power that would otherwise go to waste is true, but the extent to which this movement is likely to continue and its limitations are absolutely unknown. Now in power production in very many cases the power is utilized in the trolley and lighting service, and under these circumstances the load on the plant is extremely variable, with a large peak in the morning and afternoon. While in some few cases storage batteries are installed for charging at times of light line load, these are exceptional, and to-day steam units are installed sufficient to take care of the peak of the load permanently, which means that during the remainder of the time the engines are working at a less than maximum efficiency or a large amount of power is being wasted. The utilization of this excess power has been attempted in a number of ways. Special rates were offered to consumers of this intermittent power, with the proviso that their consumption should be intermittent. Often this condition was absent, however, and the contract was made on the assumption that the load, whatever it was, could be taken care of somehow. As a result, the number of small power consumers using electricity in this field has rapidly increased. Mechanical refrigeration has been rendered practical and efficient in a number of small refrigerator plants by this development, and the development of the compression machine in refrigeration on this account has been much extended.

GANO SILLICK DUNN

By Rodman Gilder

IT is a good thing for an electrical engineer to be a human being.

If a man's mind is devoted exclusively to volts, amperes and ohms, he will not be so much of a credit to his profession as he would be if his interests were wider and far-reaching. A good example of the engineer who becomes eminent in his profession while securing all-round development for his mind and character, is Gano Sillick Dunn.

Obliged in his fifteenth year to begin to earn his living, he became a telegraph operator. In this capacity he was employed by the Western Union Telegraph Company for six years. Though his work occupied him in the afternoon and night, he attended college regularly. In the meantime, he supported himself and helped to support his family.

In 1889 he was graduated from the College of the City of New York, with a standing near the head of his class. Two years later he graduated from the post graduate electrical course at Columbia University. The course had been recently established, and his degree was the first conferred in electrical engineering by that university. The College of the City of New York in 1897 gave him the degree of Master of Science, earned by his already prominent standing in the engineering profession and by a thesis on "The Distribution of Electric Power in Factories." His interest in this subject contributed largely to the pre-eminence of his company in the field of electric motor drive.

Immediately upon his graduation, Mr. Dunn, as an apprentice, did some special experimental work for the Crocker-Wheeler Electric Company,

whose factory, then a small affair, was located in New York City. When this work was finished, Dr. Schuyler Skaats Wheeler, president of the company, who had at first looked upon the young man as an ordinary student-apprentice, recognized his ability and invited him to stay and carry out some further work. At this time a position was being held open for Mr. Dunn in a long-established concern. When the second series of experiments was completed, the company offered him a regular position, which, after considerable persuasion on the part of Dr. Wheeler, he accepted. From that time on the Crocker-Wheeler Company has had the benefit of his continuous service.

His arduous work while getting an education brought him in contact with a great variety of men. It was then that he acquired the grasp of life and interest in humanity which distinguish him from the type of engineer who is hardly better than a human slide-rule.

His ability to deal with men and events, as well as with volts and currents, make him the best salesman his company has. It was Mr. Dunn who led the Crocker-Wheeler forces which secured the order (one of the largest electrical orders of the year) from the California Gas & Electric Corporation for three 4000-kilowatt alternators, to be driven by gas engines. These machines, the largest gas-engine-driven dynamos in the world, will supply current to the whole street railway system of San Francisco and vicinity. One of these generators was already installed at the time of the earthquake and came through the shock without damage,

though the walls of the power house fell.

A striking characteristic of Mr. Dunn is the confidence he inspires in all his business and social relations. In every organization with which he has been identified he has immediately taken his place in the front rank. At the age of twenty-five he became a director of the Crocker-Wheeler Company. In the same year he was elected vice-president of the New York Electrical Society, and, two years later, its president. At twenty-eight he was chosen vice-president of the American Institute of Electrical Engineers, and is now serving a second term in that office. He is a director of the Van Norden Trust Company, of New York.

The leading American electrical magazine has this to say of Mr. Dunn as an engineer:—"It is but seldom that one who is peculiarly successful in executive and commercial lines is, at the same time, possessed of ability to design apparatus when that designing means the most exhaustive study of abstract theoretical considerations. For many years Mr. Dunn has been the responsible and active designer of the Crocker-Wheeler machinery, and so thorough has been the preliminary study of the electrical and mechanical design that changes after the drawings are made are almost unknown, except when after a period of several years the general advance of the art and change of conditions may call for

the development of a new line of machines. Space conception, æsthetic feeling for harmony of outline, the tendency to adhere to lines of simplicity and strength,—in short, the ideal qualifications of the mechanical designer,—are, as a rule, not found associated in a mind that can readily comprehend the intricacies of wave forms and the highly complex reactions associated therewith; but Mr. Dunn has shown remarkable strength in both lines."

Aside from Mr. Dunn's extraordinary feat of placing his company within one year in the front rank of alternating current manufacturers, his achievements have been remarkable in the direct current field, to which the company was exclusively devoted until about three years ago.

As a purely mechanical inventor, Mr. Dunn could easily attain distinction were he not specially occupied with the field of electrical design. A few months ago the Crocker-Wheeler Company was in need of a machine to do certain important work in its shops. One of the company's competitors had a machine for this work which had cost in the neighbourhood of \$60,000. Mr. Dunn cleared his mind of the descriptions he had heard of the competitor's machine, got out in the shops at Ampere with his coat off, forgot everything else in the world, started from first principles, and in three weeks had built a machine for \$300 that would do the work of the \$60,000 machine.



PHOTO BY BAUMANN

HENRY CLARK SERGEANT

INVENTOR AND DEVELOPER OF THE MODERN ROCK DRILL

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THE REAL FACTS ABOUT THE GERMAN NAVY

A COMPARISON BETWEEN THE NAVAL STRENGTH OF GERMANY AND GREAT BRITAIN

By Archibald S. Hurd.



A PART from its political aspects, the sudden rise of the German Empire into the position of a first-class naval power has been one of the most remarkable technical developments in recent European history, for practically all the men-of-war have been constructed and equipped in German establishments.

The creation of this fleet—great numerically—marks a complete change of policy. In the past Germany has maintained one of the greatest, if not the greatest, armies in the world, and never has any country in modern times been pre-eminent on sea as well as on land. The Kaiser is now attempting to achieve this end, and after years of propaganda by the German Navy League he seemed to be on the road to the accomplishment of his object when the Russo-Japanese war occurred and this, so far as can be judged at pres-

ent, appears to have considerably upset the calculations upon which the new German fleet was being built. The German Admiralty is now faced by a problem of extraordinary complexity and its solution will cast an immensely increased burden on the people.

When the bill for increasing the German fleet was introduced into the Reichstag in 1897 it was a comparatively modest measure, but three years later, after the British war in South Africa against the Boers, the original measure was amended by the bill of 1900, which aimed at doubling the strength of the navy as it existed in 1896. Ten years ago the German fleet consisted merely of coast defense ships, vessels which were intended to operate on the Baltic shores of the Empire, and to protect the German coasts on the North Sea against aggression. The largest battleship building at that time was the *Kaiser Frederick III.*, of 11,000 tons. This ship and the sister vessels, which were afterwards begun, were constructed to fit comfortably the Kiel Canal which was opened in 1895. This short cut between the Baltic and the North Sea was planned at a time when battleships were much smaller





GERMAN BATTLESHIP BRAUNSCHWEIG. DISPLACEMENT, 13,200 TONS; POWER, 16,000 HORSE POWER; SPEED 18 KNOTS. BUILT AT THE GERMANIA WORKS, KIEL.

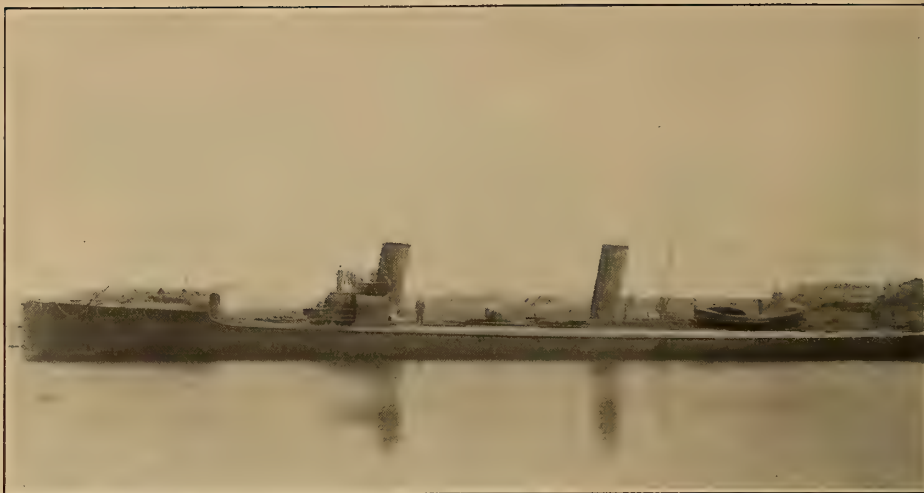
even than they were ten years ago. The work was commenced in 1886, when the battleship *Inflexible*, which did such splendid service under the present Admiral of the Fleet, Sir John Fisher, at the bombardment of Alexandria, was the biggest battleship, even in the British fleet, and displaced only 11,880 tons. The German naval authorities assumed that there would be some increase in the size of men-of-war, but they did not realize that the growth in the dimensions would be as rapid or as great as it has been.

The Kiel Canal is nearly 61 miles long and has a depth of 29 feet, and the docks are narrow, and the battleship *Kaiser Frederick III.*, which was built to fit it, has a mean draught of 25 feet 9 inches. It was assumed that the difference between the draught of this ship and the depth of the canal and the size of the locks left plenty of room for future developments, and the German people congratulated themselves upon the completion of a strategic waterway between the two seas which could be

used by the "largest man-of-war," enabling the German fleet to mass either in the Baltic or in the North Sea at a few hours' notice without having to circumnavigate Denmark, and thus run the risk of attack in Scandinavian waters. The same restricted views dominated the design of all the docks which were constructed for the German fleet. They were built to suit battleships of the *Kaiser* class, and a slight margin only was left in view of possible increase in the size of men-of-war. At this time Germany had no ambition to embark on a policy of big battleships, and it was hoped that by a reduction of non-essential weights it would be possible to construct battleships of 11,000 to 13,000 tons displacement at least equal in fighting power to British, American, and French ships of somewhat greater size. Moreover, the North Sea coast of Germany, in the opinion of British naval officers, is so shallow as to be unsuited to big ships. The German Admiralty thought that 15,000 was the extreme limit of size in other European navies, and con-
 jec-



GERMAN BATTLESHIP LOTHRINGEN. DISPLACEMENT, 13,200 TONS; POWER, 16,000 HORSE POWER; SPEED, 18 KNOTS. BUILT BY SCHICHAU, ELBING.



ONE OF 12 TORPEDO BOATS BUILT BY SCHICHAU FOR THE GERMAN NAVY. LENGTH, 62.5 METRES; SPEED, 27 KNOTS

tured that by economies of weights they could obtain equal fighting efficiency for their purpose on about 13,000 tons, especially as they had no belief in the tactical value of high speed, which then meant heavy machinery and boiler equipment, before the advent of the Parsons marine turbine and water-tube boilers of various types.

Simultaneously the British Admiralty were putting their hand to a great scheme of dock extension at

Portsmouth, Chatham, Devonport and Gibraltar. They were less cramped by financial and geographical considerations than the Germans, and they did not hold the same restricted views as to the possible development of the battleship and armoured cruiser. The new docks were consequently constructed to take vessels very much bigger than any then afloat. They were built on a generous scale so as to enable them to take a swift cruiser as long as the



GERMAN CRUISER FRIEDRICH KARL. DISPLACEMENT, 9,000 TONS; POWER, 17,000 HORSE POWER; SPEED 21 KNOTS. BUILT BY BLOHM & VOSS, HAMBURG

Powerful with a length of 500 feet and as broad as battleships of the *Majestic* class, with a beam of 75 feet and still leave a great margin at the sides and at the ends in case ships should be built even larger than those then in existence. Events have proved that the British Admiralty's policy was right, and the restricted view of the future of great navies taken by the Germans was wrong.

In a general sense, it is true that

displacement is increased so the measurements of length or depth or both are also augmented. Since the Kiel Canal was completed the British, American and French admiralities have persistently followed the policy of building big vessels in order to obtain a greater concentration of fighting force and shorten the line of battle, a tactical advantage of much importance. The standard of displacement in the past ten years in



GERMAN CRUISER HAMBURG. DISPLACEMENT, 3,250 TONS; POWER, 11,500 HORSE POWER; SPEED, 23.25 KNOTS
BUILT AT THE VULCAN WORKS, STETTIN

the size of a ship is a fair guide to its fighting power. The most modern British battleship of 15,000 tons will, as a rule, be about equal to engage in combat in the open sea with a German, French or Russian battleship of similar displacement. It is equally true that the most ingenious ship architect when he is told to increase the power of a ship, has to add to its displacement or decrease some of its other qualities—radius of action, or speed for instance. As the

battleships and cruisers has been continually upward. From the British *Inflexible*, *Nile*, and *Trafalgar*, of under 12,000 tons, the displacement rose to 14,150 in the seven battleships of the *Royal Sovereign* type, thence it went to between 14,900 and 15,000 in the battleships of the *Majestic* and *Formidable* types, while three years ago it took a further leap to 16,350 tons, which is the displacement of the *King Edward VII.* type; 150 tons was added to the *Agamem-*

non and *Lord Nelson*, and now the Admiralty have completed the *Dreadnought*—a monster battleship of 18,500 tons, and two other vessels as colossal are about to be built under the estimates of 1906-7.

The growth in the size of the battleship has been coincident with a corresponding increase in the offensive and defensive powers of these vessels. The demand has been for more guns and armour and greater speed, and constructors have found it impossible to put a quart into a pint pot. As the displacement has been augmented, the depth of water required by the ships for navigation, or the width of passage-way or dock has increased. In the British Navy, growth in size has been a matter causing no anxiety, since the navy has been wisely provided with the biggest docks and the depth of water in the naval harbours has been continually deepened.

With increase in size there has been a great increase in power. In the past ten or fifteen years science has been applied to the manufacture of guns and armour with such astonishing success that the destructive power of practically every specified gun has been almost doubled, while the power of resistance of the latest armour is immensely greater than that of the armour which was being used ten years ago. The battleship *Dreadnought* is the most colossal ship of all the navies of the world, colossal in size, colossal in fighting power, colossal in defensive qualities and colossal in speed. Most battleships of the American, French, British and Russian fleets have hitherto carried four 12-inch guns and from ten to fourteen 6-inch quick-firers, the former firing shells weighing 850 pounds and the latter shells of 100 pounds weight. One of the lessons deduced from the war in the Far East is that the 6-inch gun is comparatively ineffective, and that battleships, owing to the great ranges at which sea-actions will be fought in the future and the hardness of mod-

ern armour, have little or no use for any gun smaller than the 9.2-inch gun as used in the British service. This truth was applied in some measure in the eight battleships of the *King Edward VII.* type, with four 12-inch, four 9.2-inch and six 6-inch, was carried a step further in the *Lord Nelson* and *Agamemnon*, with four 12-inch and ten 9.2-inch weapons, and has now reached its logical conclusion in the *Dreadnought*. As a result of the actions in the Far East, which were reported upon at great length and in much detail by the British naval attachés, who had special facilities accorded to them by the Japanese, the British Admiralty decided to adopt the policy of the big gun and the big gun only in the *Dreadnought*. The *Dreadnought* carries ten 12-inch guns and has no weapons between these huge pieces and the small quick-firers—12-pounders—intended for the repulsion of attack by torpedo craft. The *Dreadnought* also has a belt of armour capable of greater resistance than any other battleship afloat, and thus protected it is calculated that she will be able to resist a blow delivered from a 12-inch gun at any range at which battles in future will be fought; $3\frac{1}{2}$ miles is regarded as an average battle range now. She is fitted with turbine machinery, and will be the first battleship in the world thus equipped. The advantage of the turbine over reciprocating engines is that a great economy in weight and space is effected, and consequently for the same power as is obtained from reciprocating engines a battleship can be built with such an economy in weight and space in the engine and boiler rooms as to leave a margin over to be devoted to more guns and armour. The British authorities in the design of the *Dreadnought* have devoted part of this economy in weight and space to increased speed and part to increased gun power, and on her speed trials, with a developed power of 23,000 H. P., a speed of 21.25 knots was attained, or one-quarter knot more than



GERMAN BATTLESHIP ELSASS. DISPLACEMENT, 13,200 TONS; POWER, 16,500 HORSE POWER; SPEED 19 KNOTS. BUILT AT THE SCHICHAU WORKS, ELBING



GERMAN BATTLESHIP PREUSSEN. DISPLACEMENT, 13,200 TONS; POWER, 18,374 HORSE POWER; SPEED, 18.60 KNOTS. BUILT AT THE VULCAN WORKS, STETTIN

was estimated, while with the maximum of 27,518 H. P. a speed of 21.6 knots was reached. This is a rate of progress in excess of that attained by most cruisers fifteen years ago, and at least two knots more than that of any battleship in a foreign fleet today.

Having the advantage of speed, it is contended that the *Dreadnought*, in battle, will be able to choose her own range, and the captain in command will naturally keep his ship at such a distance from an enemy as will enable him to pour in a steady fire from his ten 12-inch guns, with an effective range at 10,000 yards while remaining beyond the range of the 6-inch guns—range 7000 yards—carried by most existing foreign battleships.

The same policy is being adopted in the case of armoured cruisers. The British fleet in future will have no cruisers of the type which was being built ten years ago, huge ships

with little or no armour and mounting only 6-inch guns. It is not intended, in fact, to build any more large cruisers for the British Navy, but the fighting fleet will consist only of battleships and torpedo craft. The battleships will be of two types, heavy ships such as the *Dreadnought* with her ten 12-inch guns, thick mail coat of armour and speed of 21 knots; and light battleships of even greater speed, fewer guns in number than the *Dreadnought*, but almost, if not quite, as great in size and power, and a speed of about 25 knots. The development of the armoured cruiser up to the standard of the light battleship has been rapid. Ten years ago the biggest cruisers in the British Navy were the *Powerful* and the *Terrible*, each carrying two 9.2-inch guns and twelve 6-inch guns, to which four more guns of the smaller type were subsequently added.

The *Powerful* was provided with no side armour and attained a speed

of just over 21 knots. Down to the beginning of this century the British Admiralty still clung to the 6-inch gun in association with two of the 9.2-inch weapons in each big armoured cruiser. This is the fighting power of the four vessels of the *Good Hope* type. The Admiralty are now, however, completing ships which mark the beginning of the end of the armoured cruiser. The *Duke of Edinburgh* and the *Black Prince* have just been commissioned for sea service. Each of these wonderful ships carries six 9.2-inch guns and ten 6-inch weapons, in each case of a far more powerful type than was mounted in the *Powerful* and *Terrible*, and will have a speed of $22\frac{1}{2}$ knots, while their sides are reinforced with a belt of armour 6 inches thick; the deck is of thick steel; the conning tower is formed of 10-inch armour, and fore and aft there are bulkheads of armour 6 inches thick. These two vessels had been begun when the Admiralty came to the conclusion that the day of the 6-inch quick-firer had

gone, and in the four later vessels of the same type which are now under construction, the *Achilles*, *Cochrane*, *Natal*, and *Warrior*, they have substituted for the ten 6-inch guns four of the new 7.5-inch type, throwing a shell of 200 pounds. The change is a material one. The latest 6-inch gun has an energy at the muzzle sufficient to lift 3356 tons one foot in the air, while the new 7.5-inch gun produces energy sufficient to raise 10,872 tons a foot in the air. The 7.5-inch gun is, like the 6-inch weapon, a quick-firer, and costs about £2000, but in view of the immense gain in power the investment is a good one. In three even larger cruisers of later design recently laid down and known as the *Minotaur*, *Defence* and *Shannon*, each displacing 14 600 tons of water, this armament policy has been slightly varied and each vessel is given four 9.2-inch guns and ten of the 7.5-inch type. These so-called armoured cruisers—especially the last seven mentioned—are in fact, though not in name, light



GERMAN CRUISER YORCK. DISPLACEMENT, 9,500 TONS; POWER, 19,000 HORSE POWER; SPEED, 21 KNOTS
BUILT BY BLOHM & VOSS HAMBURG

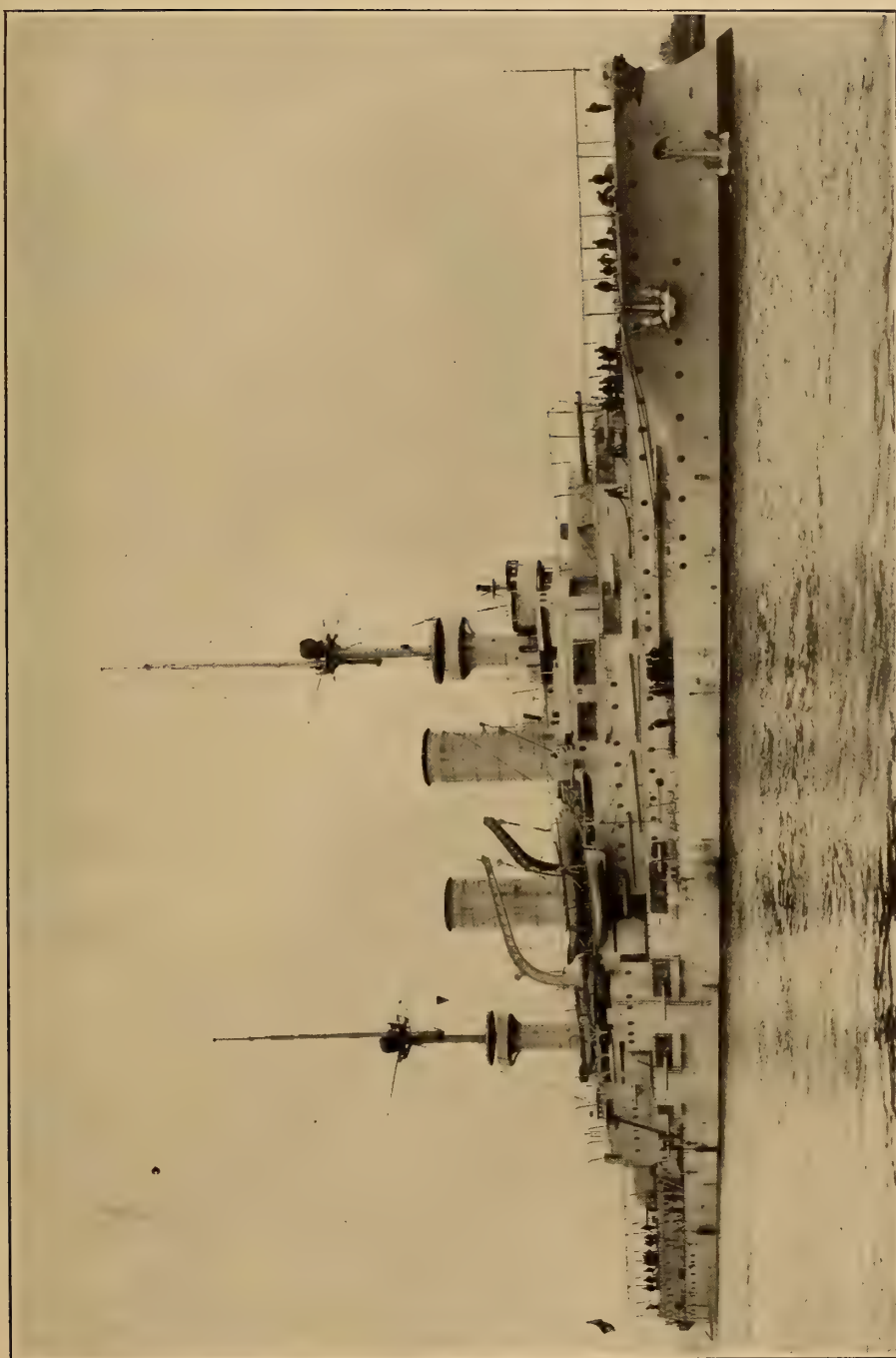
battleships. Their armour belt is so strong as to be able to resist any probable gun fire from an enemy, and their guns are so powerful that they are superior in fighting strength to the battleships of the *Majestic* class—built in the 90's—and they have the advantage of 5 knots in speed.

In view of the development already achieved in the construction of armoured cruisers with their concentration of 9.2-inch and 7.5-inch guns firing shells of 380 pounds and 200 pounds, respectively, at the rate of three and five a minute, it is impossible to draw the line between them and the battleships. The policy of concentrated fire which has been adopted in these ships will be carried a step further in the four new armoured cruisers which have just been laid down for the British fleet. Exact details are being guarded with care, but it is known that they will be more powerful than any battleship at present serving in the fleet of any European nation.

During the war in the Far East British naval attachés were afforded facilities by the Japanese for witnessing the operations which were enjoyed by no other nation. The reports which were received from these officers, who actually watched the operations, were carefully considered by the experts at the Admiralty and then were submitted to a special constituted committee of designs. This body consisted of the chief members of the great departments at the Admiralty and was reinforced by a number of private shipbuilders, while Lord Kelvin represented pure science. The designs which were discussed by this committee are those which are now incorporated in the battleship *Dreadnought* and the armoured cruisers which are about to be begun. Members of the committee, on which Sir John Fisher, First Sea Lord, and Sir Philip Watts, Director of British Naval Construction, both sat, were unanimous in praise of the new designs which incorporated a

complete revolution in warship construction. Great Britain, it is contended, has thus gained a start over all the rival Powers of Europe. Not even the most persistent of foreign attachés has been able to pierce the veil of which the Admiralty have drawn over the proceedings of this committee, and it is hoped that the ships will be complete and ready for sea before it will be necessary to take the British people into their confidence. The patriotism of the British people is not doubted, but whatever they know is known in all the chancelleries of Europe, and as the Admiralty claim to have evolved designs of unique merit, the longer they can be guarded the greater the advantage to the nation.

Is the British Admiralty alone in adopting the policy of the big ship and the big gun? In all the first-class navies the same line is being followed, and by the United States in particular. In fact, in America they led the way in the big gun theory, for in 1899, a full two years before the *King Edward VII.* class were sanctioned in England, the construction was authorized of the three battleships *New Jersey*, *Nebraska*, and *Georgia*, which, although they displace only 15,320 tons—a jump of 800 tons from the previous *Maine* class—mount four 12-inch, eight 8-inch—four in superposed turrets—and twelve 6-inch pieces, in addition to the anti-torpedo armament. In the following year two more of these ships were sanctioned—very powerful vessels with a good radius of action of 3325 miles at 10 knots, and no mean supply of ammunition. In 1902 came a further increase in size, the *Connecticut* and *Louisiana* being ordered; each displacing 16,000 tons, with improved armour protection, a speed of 18 knots, and an armament of four 12-inch, eight 8-inch, and twelve 7-inch guns, with the radical difference that the 8-inch pieces are mounted in pairs at the corners of the superstructure, while the radius of action at 11 knots is set down at



GERMAN BATTLESHIP MECKLENBERG. DISPLACEMENT, 11,800 TONS; POWER, 15,600 HORSE POWER; SPEED 18.5 KNOTS



BATTLESHIP KAISER BARBAROSSA. DISPLACEMENT, 11,130 TONS; POWER, 13,000 HORSE POWER; SPEED, 18 KNOTS. BUILT AT THE SCHICHAU WORKS, ELBING

7000 miles. In the following year a retrogression occurred, with the *Idaho* and *Mississippi* of 13,000 tons, reduced speed and smaller bunker capacity, but with four 12-inch, eight 8-inch, and ten 7-inch weapons. In the latest ships to be designed, the *New Hampshire*, *Kansas*, *Minnesota* and *Vermont*, there occurred, however, a reversion. These four vessels are improved *Connecticuts*, with the same displacement and armament, and much the same engines associated with twelve Babcock & Wilcox water-tube boilers, which are the type in most of the *King Edward VII.* class of British ships. It will be seen that in the American Navy, as in the British, there has been the same rapid tendency to an augmentation in size and to a similar effort to obtain concentration of power. In European navies the movement had not been anything like so rapid or so marked until the late war in the Far East convinced the world of the wisdom of British and American policy, which had been followed in 1904 by Japan

with the *Katori* and *Kashima* of 16,600 tons displacement and an armament of four 12-inch, four 10-inch, and twelve 6-inch pieces.

The revelation of the general trend of naval policy in the United States, Great Britain, and Japan toward unparalleled concentration of fighting power in colossal ships has been unwelcome in Germany, because the policy of construction followed in the case of recent American, British and Japanese ships bids fair to render the German Navy obsolescent long before even the scheme of augmentation passed in 1900 is actually complete. The German fleet has been built to fit the Kiel Canal and the docks at the naval ports. The Kiel Canal is shallow and its locks small, the docks lack depth, length, and breadth, and even in several of the harbours the depth of water is such that a large scheme of dredging must be undertaken before they can give hospitality to any ships corresponding in size and fighting power to those now being added to the other fleets. The Ger-

man Admiralty, when they drew up the naval programme of 1900, signally failed in prophetic vision, and the result is that the German Navy consists exclusively of comparatively small ships mounting small guns and able to steam at only low speed. The latest type of battleship now being built in Germany is the *Deutschland* and her four sisters. She displaces 13,000 tons, has a speed of only 18 knots, and carries nothing bigger than four 11-inch guns—not 12-inch be it

carried even by the vessels which, in the British navy, are still known as armoured cruisers, and the four 10-inch guns of *North Carolina*, *Montana*, *Tennessee*, and *Washington*, of the American fleet.

The construction of the latest British and American ships has dealt a blow at the German Navy from which it can recover only at immense expenditure. For the size and cost the German ships are good value for the money expended, but they are so



GERMAN BATTLESHIP WETTIN. DISPLACEMENT, 11,900 TONS; POWER, 15,000 HORSE POWER; SPEED, 15 KNOTS. BUILT BY SCHICHAU, ELBING

noted. It is a noteworthy fact that in the whole of the German fleet, including the ships building and built, there are only ten battleships which carry any larger modern weapon than the 9.4-inch gun, the latter corresponding to the pieces which are mounted in British armoured cruisers. There is not a single 12-inch gun in the German fleet, while each of the ten battleships built between 1895 and the end of the last century mounts only four 9.4-inch guns with a number of 5.9-inch quick-firers, as compared with the six 9.2-inch guns

poorly armed and possess such slow steaming qualities that, in an action, they could not bring into effective play any of the 5.9-inch weapons on which their fighting power mainly depends. They would, therefore, have to rely entirely upon the 11-inch or 9.4-inch weapons carried by their twenty modern battleships, and while they were firing from each of their vessels four of these weapons, every British battleship of the *King Edward VII.* class would be discharging a much heavier cannonade from four 12-inch guns and four 9.2-inch guns,

while the *Lord Nelson* and *Agamemnon* would be pouring in a broadside rain of shells from as many of the four 12-inch and ten 9.2-inch guns as could be brought to bear, and the *Dreadnought* herself would be firing no fewer than eight of her ten 12-inch weapons of the latest and most powerful type, this being the broadside fire. The central fact is, then, that Great Britain and America, in a

in any way comparable unit by unit to the British or American navies.

Despite these difficulties, the German naval authorities have been compelled to recognize that the big battleship has come to stay. Naval warfare consists in the massing of naval forces for the striking of overwhelming blows. In the future an admiral will have no use for any ship which is not above everything else an in-



GERMAN GUNBOAT EBER. DISPLACEMENT, 980 TONS; POWER, 1,300 HORSE POWER; SPEED, 13.5 KNOTS.
BUILT AT THE VULCAN WORKS, STETTIN

less marked degree, are actually building these great powerful ships, while Germany, owing to the restrictions of the Kiel Canal, her inadequate dock, and the shallow water in her harbours, has had to realize that she cannot imitate this naval policy until she has laid out many millions in deepening the Kiel Canal, in enlarging her docks, and in dredging her harbours, and must commence over again to build her fleet if she would possess an instrument of war

strument for striking a succession of devastating blows at an enemy. It is realized that the issue of a war will depend not upon worrying tactics by corsairs chivying merchant ships on the world's seas, but upon the clash of armed forces in battle array. The construction of the big battleship is only possible to a rich country, but it is economical for those who can afford the luxury. Great economies in weight are effected and there is a saving in the pay of the officers and

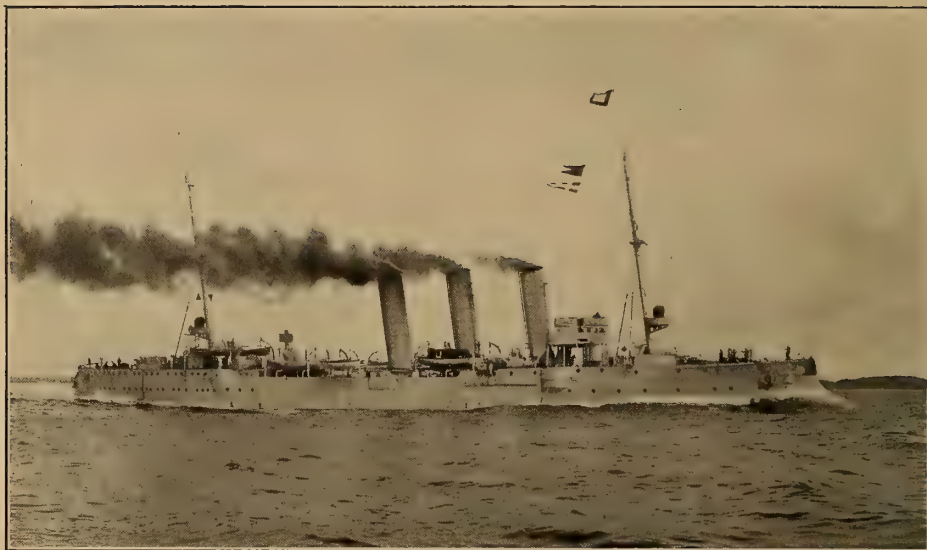


GERMAN CRUISER MUNCHEN. DISPLACEMENT, 3,250 TONS; POWER, 10,000 HORSE POWER; SPEED, 22 KNOTS

men. On a battleship of 18,000 tons a constructor can put more guns, more armour, and the engineer can obtain more speed than in two battleships of 9000 tons, and the actual cost of construction of these two smaller ships will be greater than the outlay upon the one big one, while the cost of maintenance and repairs will be larger in proportion.

The argument against the construction of such huge ships is that it is a mistake to put all one's eggs into one basket. This used to be the plea of German constructors. The fate of the *Hatsuse* and the *Yashima* in the late war in the Far East, and the sinking of the *Mikasa* in the harbour of Sasebo are powerful arguments against the construction of big ships. The two former vessels were sunk by mines or torpedoes, while the *Mikasa* went to the bottom as the result of an explosion caused by an outbreak of fire. The opponents of the big battleship can point to the destruction of these ships in the endeavour to prove the unwisdom of building such huge ships as the *Dreadnought*. It is quite true that the big battleship and the big cruiser run the same risks from torpedoes, mines, and hidden rocks as their smaller consorts,

and that the loss of a vessel such as the *Dreadnought*, costing a million and three-quarters sterling, is a national catastrophe, but these are risks which must be run if a navy is to possess vessels of great concentrated power. Only by designing and building ships like the *Dreadnought* can an admiral have under his orders a weapon enabling him to strike a decisive blow at any point in the enemy's line. This facility on the day of battle may achieve victory and save a long, costly war; whereas if the equivalent sum is devoted to small vessels, on the day of action this decisive blow cannot be struck and the opening battle, instead of being possibly the final battle, may be only the first of a series of contests during which ships of moderate size and power will hammer ships of similar limited fighting weight. The moral to be drawn from the loss of the three Japanese battleships and the destruction which overtook so many of the badly fought Russian vessels is surely an obvious one; a rich nation desiring a first-class fleet must construct big ships of the greatest power, but must also insist on the navy being maintained at an adequate standard of strength with a liberal margin



GERMAN CRUISER LUBECK. DISPLACEMENT, 3,250 TONS; POWER, 10,000 HORSE POWER; SPEED, 22 KNOTS. FITTED WITH TURBINE ENGINES. BUILT AT THE VULCAN WORKS, STETTIN

over to provide for such risks as a fleet continually at sea must inevitably run. The larger the ships the greater will be their capacity for dealing "knockout" blows to an enemy, and for this advantage a price—and a heavy price—must be paid. In the case of Great Britain with her two power standard in comparison with any European fleet, the British Admiralty must keep the navy at such a standard of strength that the loss even of two or three *Dreadnoughts* will not reduce the fleet to comparative impotence.

The purposefulness of German naval ambition is shown by the energy which is being exhibited in meeting the difficulties of the new situation. In face of the presumptive evidence in favour of the big battleship and the monster armoured cruiser, the naval authorities at Berlin have decided to make the best of what is to them a bad business. They have determined that all the battleships to be laid down in future years under the augmentation scheme of the Act of 1900 shall be of 18,000 tons displacement; they will cease building small protected cruisers, on which large

sums have been expended, meantime strengthening their existing ships of this class; they will construct annually an additional armoured cruiser of 15,000 tons, of the heaviest gun power, and an extra torpedo boat division—six boats. This departure, this abandonment of the small battleship, with its comparatively poor gun power, and the lightly protected cruiser is an extraordinary admission of the failure of the policy pursued hitherto, and casts a reflection on the value which the German Admiralty itself attaches to the vessels of small size built in the past seven years. The growth in battleship displacement from just over 13,000 to 18,000 tons at one jump will be taken to mean that they realize that the small battleships, some of them not yet launched, are already more or less obsolescent.

Germany is beginning her work afresh. She stands to-day in relative strength to Great Britain little in advance of the position she occupied in 1897, and before she can utilize these projected ships of huge power she has to push on with costly dock extension work and dredging opera-

tions, and must face the necessity either of creating a base on the North Sea or widening and deepening the Kiel Canal. Not even German energy, however, can get over the disadvantage due to the shallowness of parts of the North Sea which renders it, in the opinion of naval officers, unsuited to ships of the largest size, unless the draught is kept down at the expense of great increase of beam, which in itself is a serious trouble in navigating narrow waters and in docking.

These naval projects will cast on the people of the German Empire a heavy burden, and the pressure of the military system is not decreasing. Prior to the inauguration of the new policy, the sum spent on the navy (1896) amounted to £4,312,995. To-day the expenditure on the fleet has reached £11,424,845, and it is semi-officially admitted that in 1912 the outlay will be no less an amount than £16,400,000. Even by 1912 Germany will possess only eighteen battleships of the new 18,000-ton class, and the battleships of the smaller sizes of which the fleet now entirely consists will be absolutely obsolete. The prospect for the German Empire is not cheerful.

On the other hand, as the war between Japan and Russia conclusively showed, sea power does not consist in the mere possession of ships. The strength of a navy lies primarily in the high standard of efficiency attained by officers and men in their warlike duties. The word "efficiency" is written all over the German Navy, and this is a consideration of which account must be taken in assessing its fighting value. There is probably no navy in the world in which a higher standard of efficiency has been reached by officers and men. It is the world's only military navy; its officers are soldiers and its men are soldiers, and its discipline is the discipline of the German Army. It is a new creation, and it suffers from

none of the traditions which are apt to clog the wheels of progress in older forces. The German Navy is intent on justifying its existence in the eyes of the people of the German Empire. This is largely the explanation of the high standard of efficiency which has been reached; this and the personal interest which the Kaiser himself has devoted to the training of the fleets at sea. Every navy in the world is an expression of policy, and the German Navy is the symbol of the *welt politik* of an empire with an increasing trade requiring over-sea markets and of a people too big for even the German Empire, who desire to find fresh openings for their sons and daughters and whom on his part the Kaiser wishes to see settle in colonies under the German flag. This is a new policy, and it is these ideas which have prompted Germany to make a strenuous bid for sea power. She possesses already dominating land power, owing to the size and prestige of her army, and now she is seeking the power on the world's seas which a navy only can confer on her.

It is this development of her fleet, this challenge of Britain's position as the supreme naval power of the world, this interference with the traditional rôle of Great Britain in European waters and the counter moves made by the British people, which lie at the root of the relations now existing between the two peoples. At no point do their frontiers meet, in no part of the world is there any active subject of dispute, yet there is ill will, and the explanation is to be found in Germany's efforts to create a fleet to rival the British Navy and the spirited response made by the British people. The contest has been in progress since the Navy Act of 1897 was passed by the Reichstag, and to-day Germany realizes that she has made little progress if the big ship is the dominating factor in naval warfare that most naval officers hold in the light of recent experience.

THE INCREASED PRODUCTION OF GOLD AND ITS RELATION TO THE STANDARD OF VALUE

By Alexander E. Outerbridge, Jr.

IN a paper on "Recent Progress in Metallurgy," printed in the November issue of "The Journal of the Franklin Institute" (reprinted in full or in part in a number of magazines and newspapers), the remarkable increase in production of gold in recent years was alluded to *en passant*. This has called forth a number of inquiries, and it is thought that some of these questions, with replies thereto, may prove interesting and instructive to readers of *CASSIER'S MAGAZINE*. The following are a few of the more important questions:—

1. "What percentage of gold enters into the arts? All the balance that is locked up seems useless except so far as paper certificates are issued as its representative, and used in exchange for other commodities."

2. "As it takes more gold (or representative certificates) now to obtain the services of a workman, or any of the necessities of life, than was required a century ago, is it not because there is more gold being produced and because it (or its representative certificates) is more largely held by a larger percentage of the population of the earth?"

3. "If a cheap and universal means of extracting gold from clay and low grade ores, also from sea water (which contains a minute proportion) should be discovered, what would be the effect upon the world's standard of values, should we then return to the first principles of trade, and live by the barter of actual commodities?"

4. "Certificates of the possession or existence of railroads and their equipment, or of factories or other buildings, are only of value in proportion to the profit made by their use, but a

railroad or a factory locked up would be useless, and the stock certificates representing them would be of little value as media of barter. Why is it that gold locked up in a vault and unproductive should occupy such a different position?"

Questions of this nature have been discussed for ages by theorists, economists, statesmen and others, without producing very definite solutions, and they are likely to continue to be the subject of debate indefinitely.

One hundred and thirty years ago Adam Smith, in his profound work on the "Causes of the Wealth of Nations," said regarding increase in production of precious metals:—"When more abundant mines are discovered, a greater quantity of the precious metals is brought to market, and the quantity of the necessities and conveniences of life for which they must be exchanged being the same as before, equal quantities of the metals must be exchanged for smaller quantities of commodities. So far, therefore, as the increase of the quantity of the precious metals in any country arises from the increased abundance of the mines, it is necessarily connected with some diminution of their value.

"When, on the contrary, the wealth of any country increases, when the annual produce of its labor becomes gradually greater and greater, a greater quantity of coin becomes necessary in order to circulate a greater quantity of commodities; and the people, as they can afford it, as they have more commodities to give for it, will naturally purchase a greater and greater quantity of plate. The quantity of their coin will increase from necessity; the quantity of their

plate from vanity and ostentation, or from the same reason that the quantity of fine statues, pictures, and of every other luxury and curiosity is likely to increase among them."

Regarding the increase in production, it appears that the annual gold production of the world has nearly doubled in the past ten years. In the United States it has increased from 2,568,132 ounces in 1896 to 4,265,742 ounces in 1905, according to official statistics of the Bureau of the Mint.

Dr. Adolf Soetbeer's tables giving the estimated production of gold in the world for a long series of years, show that in 1886 the total production was a little over \$100,000,000 in value. The latest estimates of production in the year 1906 show total value of a little under \$400,000,000; thus it appears that production of gold has almost quadrupled in twenty years, and the question naturally arises, therefore, in view of this enormous increase, what will happen when the world becomes surfeited with the metal which is at the same time a commodity and a standard of value?

Have we, indeed, already reached the saturation point where cost of living has increased by reason of the decline in value of the standard, due to increased production? First, let us compare the value of the annual production of gold in the United States (which is one of the three leading producers in the world) with the value of some other products that attract far less notice, and we will discover some surprising results. If, for example, we should be asked to state, offhand, our idea of the relative value of the annual production of gold in the United States as compared with that of eggs, we would probably say that is a very silly question for, of course, the gold output so far exceeds the value of eggs laid annually that comparisons would be absurd.

The twelfth Census Report (1900) shows that in 1899 the value of eggs produced on farms in the United States was \$144,286,158, while in the

same year the value of the gold output of the country was \$71,053,400, or less than one-half that of the "hen fruit."

In 1905 the value of the gold production in the United States, according to official figures of the mint bureau, just issued, was \$88,180,700. The egg output in 1905 was probably more than double this in value. The fact is that the value of the annual gold crop is, in comparison with many other crops, quite small.

The report of Secretary Wilson, of the Department of Agriculture, for 1905, which has just been made public, says:—Corn remains by far the most valuable crop, estimated at \$1,167,000,000 in the United States; cotton, \$640,000,000; hay, \$593,000,000; wheat, \$490,000,000; oats, \$306,000,000, and so on. Again, the value of the surplus products of the farms exported in 1905 reached the enormous sum of \$976,000,000.

The value of the 22,992,380 long tons of crude pig iron produced in the United States in 1905 is given in the Report of the United States Geological Survey as \$382,450,000, more than four times that of the gold product, and the value of the copper output in the same period of time was \$139,795,716, nearly one and a half times that of the gold. The value, at the mines, of bituminous coal marketed in 1905 exceeded that of gold more than three and a half times, and that of anthracite coal more than one and a half times.

These comparisons of relative values might be greatly extended without exhausting the list of available illustrations, but it is thought that sufficient examples have been given to show that although the production of gold has almost quadrupled in twenty years it is as yet a comparatively small annual contribution to the world's wealth. That the price of labor and of all luxuries and of most necessities of life have enormously advanced in recent years there is no doubt, but that this increase is due to increased production

of gold is open to argument from many points of view. When we consider the natural increase in population, with the increased requirements and expenditures of the people, it seems that we are still very far indeed from approaching the saturation point of production of gold, that is, the point which might depreciate the recognized standard of value the world over.

With regard to the first question, viz.:—"What percentage of gold enters into the arts?" I cannot offer a better reply than to give the words of a former Director of the Mint, who prosecuted an elaborate investigation of the subject extending over several years. "The amount (of gold and silver) annually used for coinage and

United States by addressing circular letters to all manufacturers whose addresses I could obtain, who consume gold or silver in the preparation of chemicals and in the manufacture of jewelry, watch-cases, and other solid or plated wares. The circular referred to requested that they would specify the various forms of the metals used, whether United States coin, foreign coin, and old manufactured articles reworked or bullion. The replies that have been received, while incomplete as to the total consumption, are valuable in exhibiting the proportion of the different specified forms used, and also show that the gross amount would be in excess of estimates previously made.

"The total consumption is as follows:

	United States Coin.	Old Manufactured Articles, Including Foreign Coin.	Bullion Bars and Native Grains.	Total.
Gold.....	\$1,473,259	\$386,160	\$3,989,081	\$5,848,500
Silver.....	179,905	144,239	2,288,588	2,612,733
Total.....	1,653,164	530,399	6,277,669	8,461,233

exported is readily ascertained. The Mint records show the one and the customs returns the other. But to obtain accurate statistics of the amount annually consumed by abrasion or loss of coin, and used in the arts, manufactures and ornamentation, is a very difficult task. The annual consumption of the precious metals for the latter purpose was placed by Humboldt, in 1803, at \$6,000,000 for France and \$23,000,000 for Europe. Mr. N. Jacob, in 1831, from a careful review of the various occupations using gold and silver in manufactures and ornamentation, made the annual consumption in the British Kingdom, for other purposes than coin, to be gold of the value of \$8,185,000 and silver \$4,100,000. His conclusions for Europe, then, were that gold and silver were thus annually used to the value of, in—

Great Britain.....	\$12,285,000
France.....	6,000,000
Switzerland.....	1,750,000
The remaining countries.....	8,025,000
Total.....	\$28,060,000

"I have attempted to secure further statistics of the consumption in the

"Out of 3506 addressed, 1401 replies were received; and of the latter, 448 were manufacturing and consuming gold and silver, and reported the above amounts, leaving 2105 not heard from. It is obvious that the estimates of this office are not in excess of what probably would have been reported as the actual amount of the precious metals used, had complete and full returns been made.

"From all the information obtained, it may be safely assumed that the annual consumption in the United States of precious metals in all forms now averages seven million dollars of gold and five million dollars of silver, making a total of twelve million dollars; and fuller statistics may show a greater amount thus used. In estimating the amount of domestic production appropriated annually for this use, I have added one-third to the value of such bars furnished from the New York assay office, which gives the following consumption for the last fiscal year:—

"Gold, \$3,869,125, and silver, \$5,977,300; and an average annual consumption, for the last six years, of

gold, \$4,458,104, and silver, \$4,854,527. The annual coinage export and consumption of bullion produced in the United States (not including old plate and coin) for the last and five preceding years, appears, from data received, to be as follows:—

FISCAL YEARS.	GOLD.			
	Coinage.	Used in Arts and Manufactures.	Exported (reported by Bureau of Statistics.)	Total.
.....	\$25,034,031	\$4,578,328	\$3,878,543	\$33,490,902
1875.....	25,851,983	5,382,098	2,233,775	33,469,856
1876.....	33,887,086	4,153,184	1,888,896	39,929,166
1877.....	42,125,662	3,687,192	1,084,536	46,897,390
1878.....	45,922,340	5,078,701	205,319	51,206,360
1879.....	35,005,959	3,869,125	24,774	38,899,858

FISCAL YEARS.	SILVER.			
	Coinage.	Used in Arts and Manufactures.	Exported (reported by Bureau of Statistics.)	Total.
1874.....	\$5,764,538	\$4,406,560	\$27,153,496	\$37,324,594
1875.....	10,291,805	4,237,841	17,197,914	31,727,560
1876.....	19,730,654	3,812,018	15,240,344	38,783,016
1877.....	24,543,939	3,774,240	11,475,394	39,793,573
1878.....	25,036,188	5,210,152	15,035,045	45,281,385
1879.....	22,951,768	5,977,300	11,883,064	40,812,132

In the next succeeding annual report (1880) the Director says that no fewer than 7290 additional letters were addressed to persons using gold and silver in the arts and manufactures; 2791 replies were received, showing a much greater quantity of gold and silver consumed than previously reported. Without reproducing the tables, it is sufficient to state the conclusions, viz:—"The estimate of last year that \$5,000,000 of silver and \$7,000,000 of gold were during the year appropriated for purposes other than coin, is sustained as to silver and increased as to gold to \$10,000,000 if not more."

The Report of the Director of the Mint for the year 1889 estimates the value of gold used annually in the United States in the industrial arts at, approximately, \$16,700,000. The same report gives the total value of the gold product of the country in 1888 as \$33,167,500. According to this showing, therefore, the proportion of gold consumed in the arts was in that year almost 50 per cent. of the total production.

These exceedingly interesting and important investigations have been continued and the Report of the Director of the Mint for the fiscal year ended June 30, 1906, which has

just been issued, gives a table showing the total amount of gold bars furnished (by the Mints) for use in manufactures and the arts and classification of the materials used since 1880. The table shows a varying consumption, depending upon, or

bearing a close relation to, the ever changing industrial prosperity of the country, thus:—In the calendar year 1891 the value of the gold used in the arts and manufactures rose to \$19,686,916. In 1894 it fell to \$10,658,604. During the past decade there has been a steadily increasing amount of the precious metal consumed annually in manufactures and arts, as the following table shows:—

1896.....	\$11,395,934
1897.....	11,870,231
1898.....	13,565,879
1899.....	17,847,178
1900.....	20,148,142
1901.....	21,868,956
1902.....	25,682,847
1903.....	29,063,551
1904.....	28,655,963
1905.....	33,208,615

The value of the total production of gold in the United States in the calendar year 1905 is officially stated to have been \$88,180,700. It thus appears that the value of the metal consumed in the arts was more than 37½ per cent. of the total production in that year. The mint bureau estimates the world's consumption of gold in the arts in 1905 at \$85,122,000 and the total production in that year at \$376,289,200.

According to these estimates, therefore, it appears that the world's consumption of gold in the arts in 1905 was equal to about 96½ per cent. of

the total production of the United States and over 22 per cent. of the total world's production in that year.

I have before me a table giving the estimates of the United States Treasury Department of the stock of gold coin and bullion in the United States at the close of each fiscal year for twenty-three years past. In 1873 the total gold in the country (coin and bullion) amounted in value to \$135,000,000. In that year the population was 41,677,000 and the per capita gold value was \$3.23. In 1906 the value of gold coin and bullion in the United States had increased to \$1,472,995,209, the population had increased to 84,662,000, and the per capita value of gold to \$17.40. Thus it appears that while the population has a little more than doubled since 1873, the per capita proportion of gold in the country has increased more than five times in less than a quarter of a century.

Does this indicate a plethora of gold? In order to consider intelligently the subject from this point of view we must look at the increase in wealth of the country, the value of property, the expansion of trade and its monetary requirements as shown by reliable statistics.

The United States Census estimate of the true value of property in 1900 in the United States was \$88,517,306,775. In 1904 the estimate was \$107,104,211,917, an increase of over eighteen and a half billion dollars, or more than four and a half billion dollars a year.

It is stated in an article on "Credit Currency," in "The North American Review," that the national banks have at the present time deposits from the public amounting to \$5,897,770,000, these deposits having increased in one year \$382,000,000 and having increased from \$725,000,000 since the organization of the system in 1866.

The total stock of money in the United States Dec. 31, 1905, is shown in a governmental statistical table to have been no less than \$2,689,700,000, distributed thus:—

Gold in banks and public treasuries.....	\$955,800,000
Gold in circulation.....	465,000,000
Silver—full tender.....	568,300,000
Silver—limited tender.....	118,500,000
Uncovered paper.....	582,100,000
Total.....	\$2,689,700,000

A very recent (unofficial) calculation shows the total stock of money in the United States Dec. 31, 1906, to have been \$2,869,000,000, an increase in one year of nearly 8 per cent. The national bank loans increased about \$370,000,000, or over 9 per cent. in 1906 as compared with 1905. Bank clearings increased in the same period about 12½ per cent., i. e., from \$129,500,000,000 to \$145,540,000,000.

The net earnings of railroads increased nearly 26 per cent. in eleven months of 1906, or from \$795,000,000 in 1905 to \$900,000,000 in 1906.

The production of pig iron was given in the beginning of this paper for the year 1905, viz., 22,992,380 long tons, valued at \$382,450,000. Great as are these figures, they are cast into the shade by those of 1906, which can be now closely approximated at 25,310,000 long tons, having value in round figures of \$500,000,000, as compared with gold production of \$88,000,000 in the same period. Increase in production and value of all products in 1906 has been recorded with scarcely an exception; all this industrial activity has created an enormously increased demand for capital for extension of established businesses and for the exploitation of new enterprises. More money is needed to finance these legitimate enterprises, and one of the results of this discussion is to show, from a number of different points of view, the inadequacy of the stock of gold in the world to-day to fulfill its primitive function as an intermediary for barter or a direct medium of exchange. Were it not for "credit currency" the world's business could not be transacted to-day.

The increase in production of gold has fallen far short of keeping pace with the expansion of trade and increase in value of other products. As a standard of value gold will con-

tinue to hold its position unchanged, judging by all present indications, for the increased production barely serves to maintain the equilibrium that has been so long established.

It is curious that a question should arise as to the stability of the standard of value at a time when the wheels of industry are revolving at the highest speed, and while a prolonged stringency has prevailed in the money markets of the world. The reasons, therefore, are somewhat obscure and their further consideration would extend this article beyond its prescribed limits.

Without attempting to answer seriatim the questions propounded in the beginning of this paper, an effort has been made to cover the ground as fully as may be. Comparative figures have been given which seem to indicate that the increased cost of labour and of the necessities of life cannot be attributed to a plethora of gold, but must be due to other causes. The increase in population, in material wealth of the masses, their increased necessities, and the enormously greater consumption by the people of things which were formerly regarded as luxuries, only obtainable by the comparatively few rich persons, has far more than counterbalanced the increase in production of gold, so that there is no likelihood, even in the event of the discovery of new methods of obtaining gold more economically from sources at present unavailable, that the production will approach the point of saturation. Rather does it appear that the trend of future events points in an opposite direction. There was, it is true, a time in the world's history when gold was too precious to be considered as a standard of value; various base metals, such as iron, tin, copper, etc., have fulfilled that function, then came silver, which for a long period re-

mained fixed in value and was regarded as the monetary unit par excellence.

The question whether gold will always remain the fixed standard of value for all other commodities will no doubt prove in the future, as it has proved in the past, a fascinating topic for argument. But, from present indications, there is no reason to fear that the purchasing power of the yellow metal has declined or will decline through a surfeit of production.

If indeed an actual transfer, from hand to hand, of gold coin were required in modern transactions there would not be enough to go round, or even half-way round. The world's business affairs could not be transacted on such a basis, even if the production of gold should be increased in the next decade far more than in the last ten years. Apart from the insufficient quantity of gold in the world to-day, to serve as a direct medium of exchange, the inconvenience and expense of transfer from place to place of gold coin in bulk would be very great. Some careful tests made years ago in the Royal Mint showed an appreciable loss by attrition of gold in the mere transporting of a lot of new sovereigns from one room to another.

We have a standard yardstick and standard weights and measures carefully kept in Washington, which are not to be used in commercial transactions; so we have in the government vaults quantities of standard gold coins, each coin being represented in the money markets of the world by a paper certificate issued by the government, this certificate being exchangeable at par for gold, has exactly the same value as the coin it represents as a medium of exchange. Thus the standard is preserved intact, while the certificates may be renewed when defaced or worn out.

THE SHAWINIGAN HYDRO-ELECTRIC POWER PLANT

THE LATEST DEVELOPMENTS AND EXTENSION OF THE GREAT STATION AT
SHAWINIGAN FALLS, CANADA

By Wallace C. Johnson

The following paper demands the interested attention of the members of the engineering profession; mingled with feelings of sadness, in view of the fact that its brilliant author passed away only a few weeks after it was written. Mr. Johnson was a native of New York, and received his technical education at the Worcester Polytechnic Institute, and after practical experience in the office of Mr. Clemens Herschel and with the Holyoke Water Company, he undertook the work of the Niagara Falls Hydraulic & Manufacturing Company, developing the important power station below the Falls on the American side. In addition to this large undertaking, he acted as engineer for a number of hydraulic-power plants, including those of the Bodwell Power Company, at Oldtown, Maine; the Albion Power Company, Waterport, N. Y.; the Empire State Power Company, Mohawk, N. Y.; the Hannawa Falls Power Company, at Hannawa Falls, on the Raquette River, New York, and, latest of all, the great plant at Shawinigan Falls, in the Province of Quebec, from which power is transmitted to Montreal, more than 80 miles distant. It is of his latest addition to this last plant that Mr. Johnson writes in the following article; and, taken in connection with the papers by himself and by Mr. Mershon in our issue for June, 1904, it forms the complete story of an important direction of a great source of power in nature to the use and convenience of man.—The Editor.



IN CASSIER'S MAGAZINE for June, 1904, there appeared two articles relative to the hydro-electric development of the Shawinigan Water & Power Company, on the St. Maurice River, at Shawinigan Falls, in the Province of Quebec, Canada. Mr. Ralph D. Mershon,

then the consulting electrical engineer of the Shawinigan Water & Power Company, described the electric equipment, and in particular the line by which current at 50,000 volts is transmitted from Shawinigan Falls to Montreal, a distance of about 85 miles. This transmission line and its appurtenances were designed by Mr. Mershon.

In the original installation of the Shawinigan Falls power plant, between 1898 and 1904, the discharge of the St. Maurice River was utilized at the point where the Shawinigan

Falls give a total head of about 150 feet, and an actual working head of 130 feet, with an estimated flow of about 10,000 cubic feet of water per second. The general arrangement of the plant can be gathered from the accompanying maps, showing the location of the falls and watershed of the St. Maurice River, and the relation of the power house to the city of Montreal.

At the time of the installation of the original plant, it was shown that the total flow of the river would enable about 100,000 H. P. to be developed, taking into account the natural flow of the river. By the utilization of the lakes on the watershed this capacity could be largely increased, a matter of importance in connection with the future development of the plant. The original plans included the delivery of 10,000 hydraulic horse-power to the Pittsburgh Reduction Company for use in its own power house for the manufacture of aluminium, in addition to which, 15,000 H. P. were developed in the power house for electrical distribution to Montreal, a distance of 85 miles, and to other nearer points, for the operation of railways and the conduct of electrochemical industries.

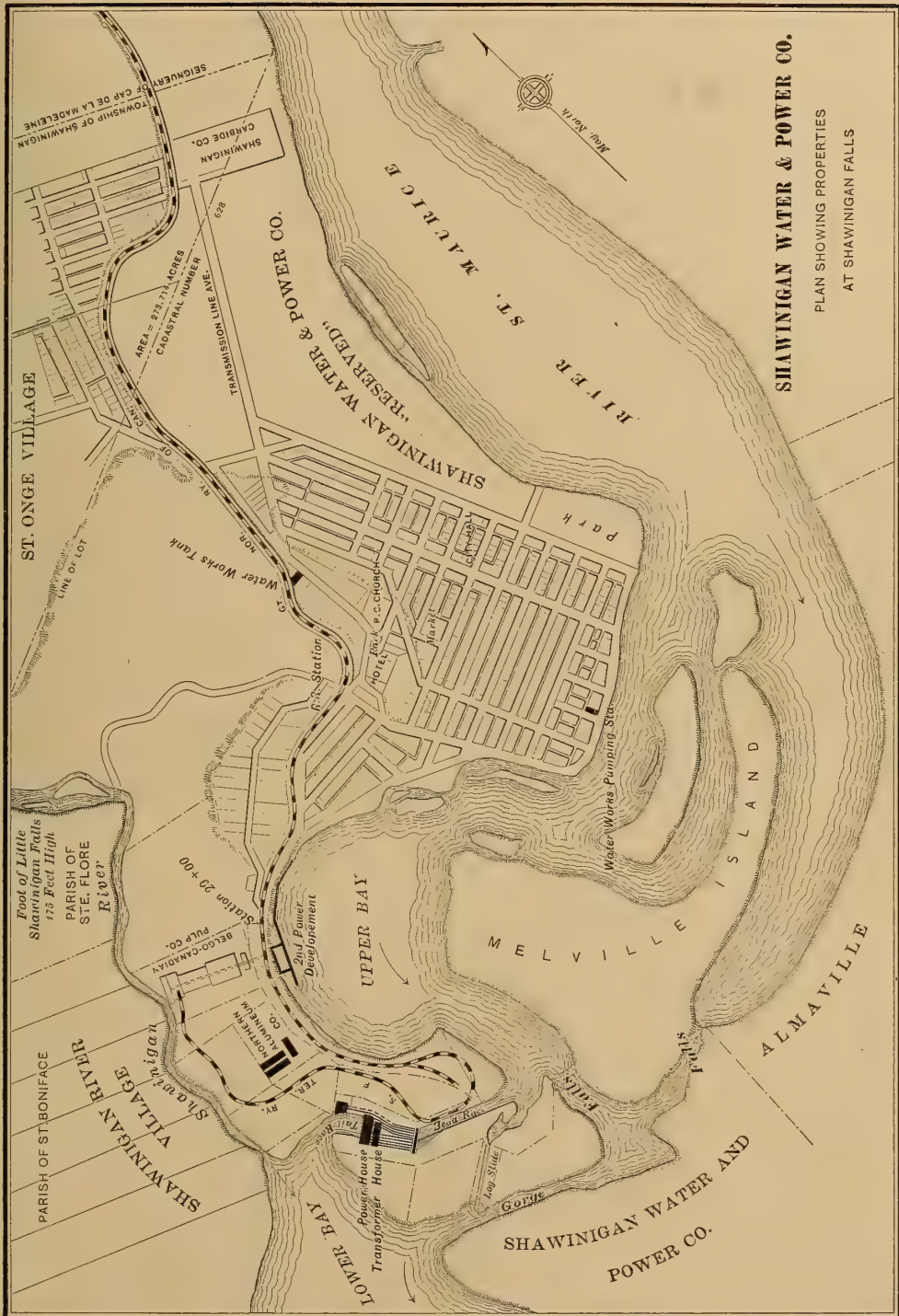


FIG. 1.—THE PLANT OF THE SHAWINIGAN POWER COMPANY



FIG. 2.—MAP OF THE WATERSHED OF THE ST. MAURICE RIVER

The writer, who was then the chief engineer of the company, contributed to the issue of this magazine for June, 1904, an article describing the plant in general, and in particular the hydraulic equipment by which the power was developed. At that time there were installed in the power house at Shawinigan Falls three units, each consisting of a water wheel, operating under a head of 125 feet, and direct-connected generator, and each unit capable of developing 5000 H. P. It was mentioned in the above article that it had

already been determined to install a fourth unit of 10,500-H. P. capacity. This fourth unit is now installed and in operation. A second transmission line to Montreal has been built, and many changes and additions have been made in the equipment. The purpose of this article is to describe briefly the various changes and additions.

When the installation of the fourth unit was decided upon, it was desirable to take the water for supplying this unit from an opening in the forebay already existing. This open-

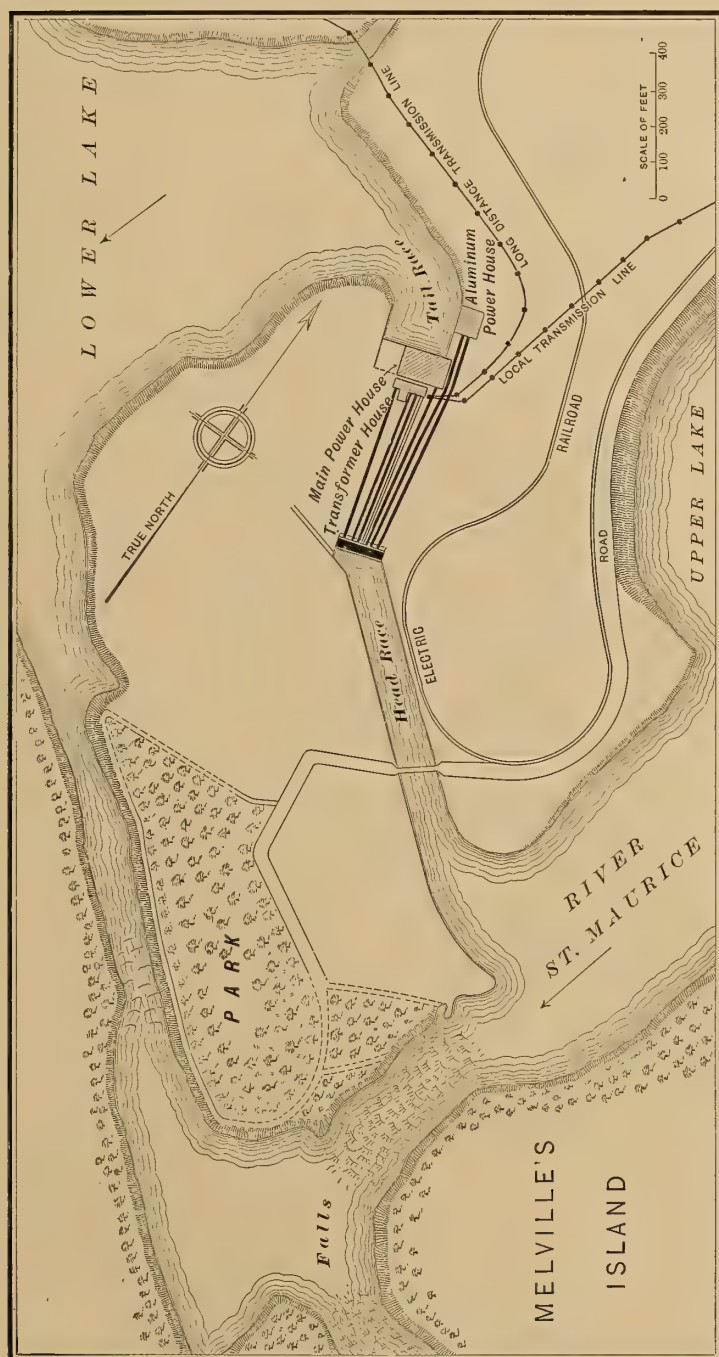


FIG. 3.—AN ENLARGED MAP OF THE SHAWINIGAN POWER PLANT, SHOWING THE LOCATION OF THE TRANSFORMER AND POWER HOUSES, THE PENSTOCKS, AND THE HEAD AND TAIL RACES

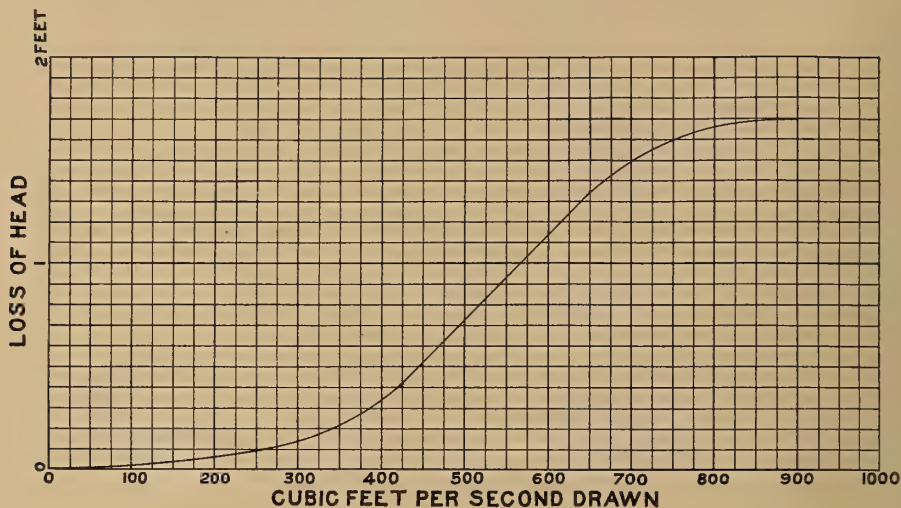


FIG. 4.—DIAGRAM SHOWING RELATION OF LOSS OF HEAD TO DISCHARGE

ing consisted of a plate steel tube inserted in the concrete, which was 9 feet in diameter, through the wall, a distance of 29 feet.

The installation of the wheel in the power house involved a penstock 450 feet in length, from the forebay wall. This pipe it was determined to build 12 feet in length, and to taper a section 18 feet in length, continuing the taper to the 9-foot pipe already in place. It was understood that the high velocity at the entrance, and through this 9-foot section of pipe would have the effect of somewhat reducing the head, but consideration of construction made it necessary to use the existing design. On the test of the water wheel to be described, the loss of head between the level of the water in the forebay and an air vent 90 feet from the upper end of the penstock varied with the quantity of water drawn, according to the diagram, Fig. 4. Specifications which were drawn by the writer stated the form which the wheel should take, type of runners, form of grate, etc., with the usual specifications as to the kind of wheel and materials used in the different parts of the work. The contractors were required to guarantee the development of 10,500 H. P. when the wheel was running

at 180 revolutions per minute under a head of 135 feet, and an efficiency of at least 78 per cent. when the wheel was developing 9000 H. P. or more. These specifications also required that the speed regulation should be within 10 per cent for all changes of load, within 2 per cent. for load changes of 25 per cent. or less, within 1 per cent. for load changes of 10 per cent or under.

Under the above described specifications the I. P. Morris Company, Mr. A. M. White, engineer, undertook the design and building of the wheel. The detail plans, as they were developed, being subject to the approval of the writer as chief engineer of the Shawinigan Water & Power Company. After the wheel was installed a test was made of its power and efficiency. The power was measured by using the direct-connected generator as a dynamometer, the generating having been previously tested at the factory. The quantity of water to be used being at the maximum power of the wheel, some 900 cubic feet per second could not be measured over any weir, which it was practicable to construct in the tail race. The measuring of the water was therefore made by a Pitot tube installed in the penstock.

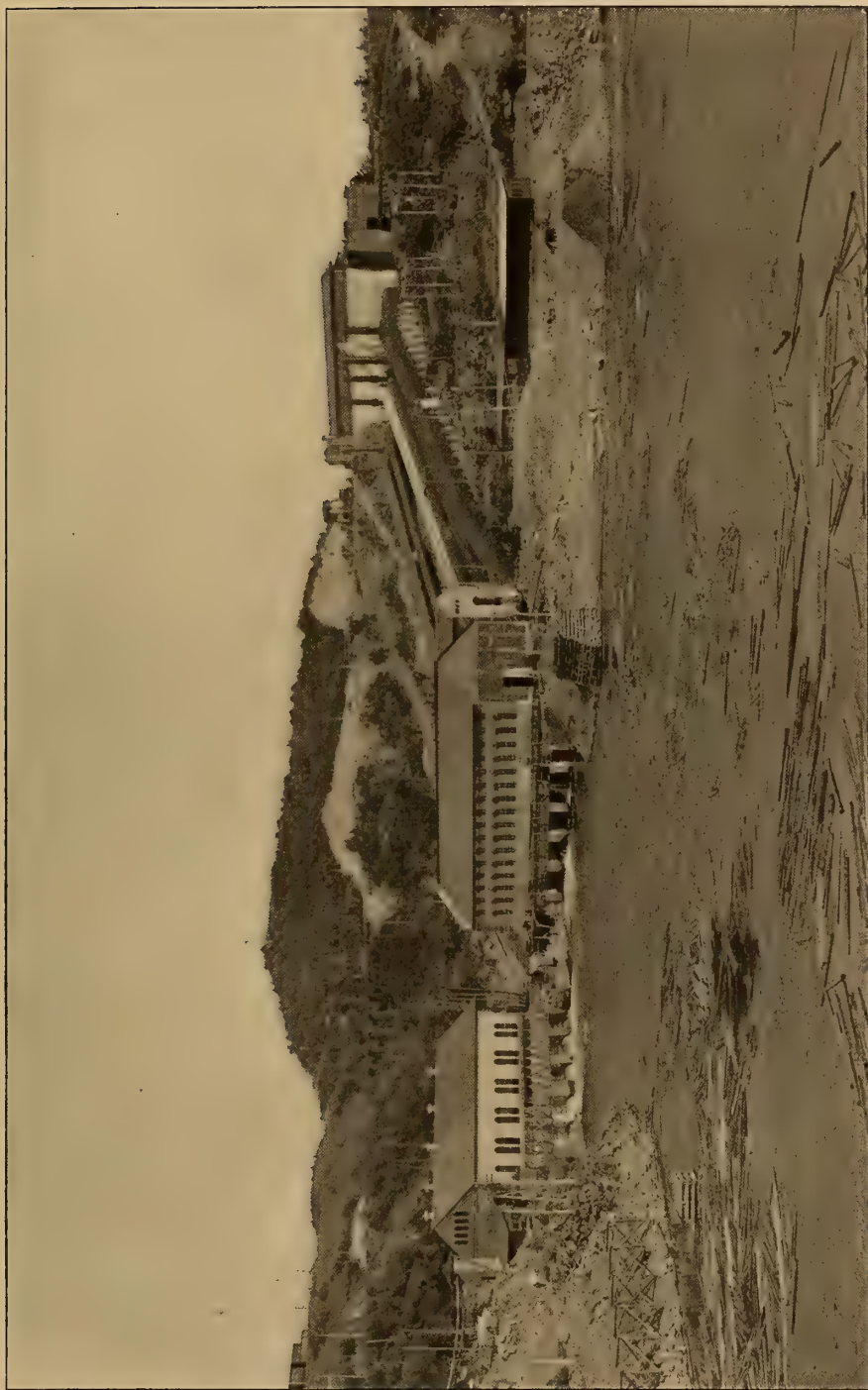


FIG. 5.—GENERAL VIEW OF THE POWER PLANT AT SHAWINIGAN FALLS



FIG. 7.—VIEW UNDER THE SWITCHBOARD GALLERY, SHOWING ARRANGEMENT OF THE BUS BARS

Previous to making this test a test had been made of one of the 5000-H. P. units already installed, taking water through a 9-foot pipe of similar construction to the penstock to this fourth unit. The water in this test had been measured by using the Pitot tube, and also by measuring over a sharp-edged weir 16 feet in length installed in the tail race, up to a discharge of about 260 cubic feet per second. Calculating the results of the Pitot tube by the formula $V = \sqrt{2gh}$, with a constant of unity, the comparison showed that the result of the Pitot tube measurements were uniformly from 1 per cent. to 2 per cent. greater than the results shown by the weir measurements. This 9-foot tube was exactly similar in construction to the 12-foot tube

supplying this wheel. It was considered that this experiment was a confirmation of previous experiments tending to show the correctness of the formula, and this method of measurement was therefore considered to be sufficiently accurate for the purposes of the test of this wheel. The following curve shows the result of the test as to power and efficiency of this wheel. The test was made by Mr. White, and the writer, with an unusually competent force of assistants. Every precaution was taken to have all the measurements correct. While there are numerous examples of this type of wheel in operation at various points in Europe, there are very few examples in this country, and at the time this wheel was designed nothing of this

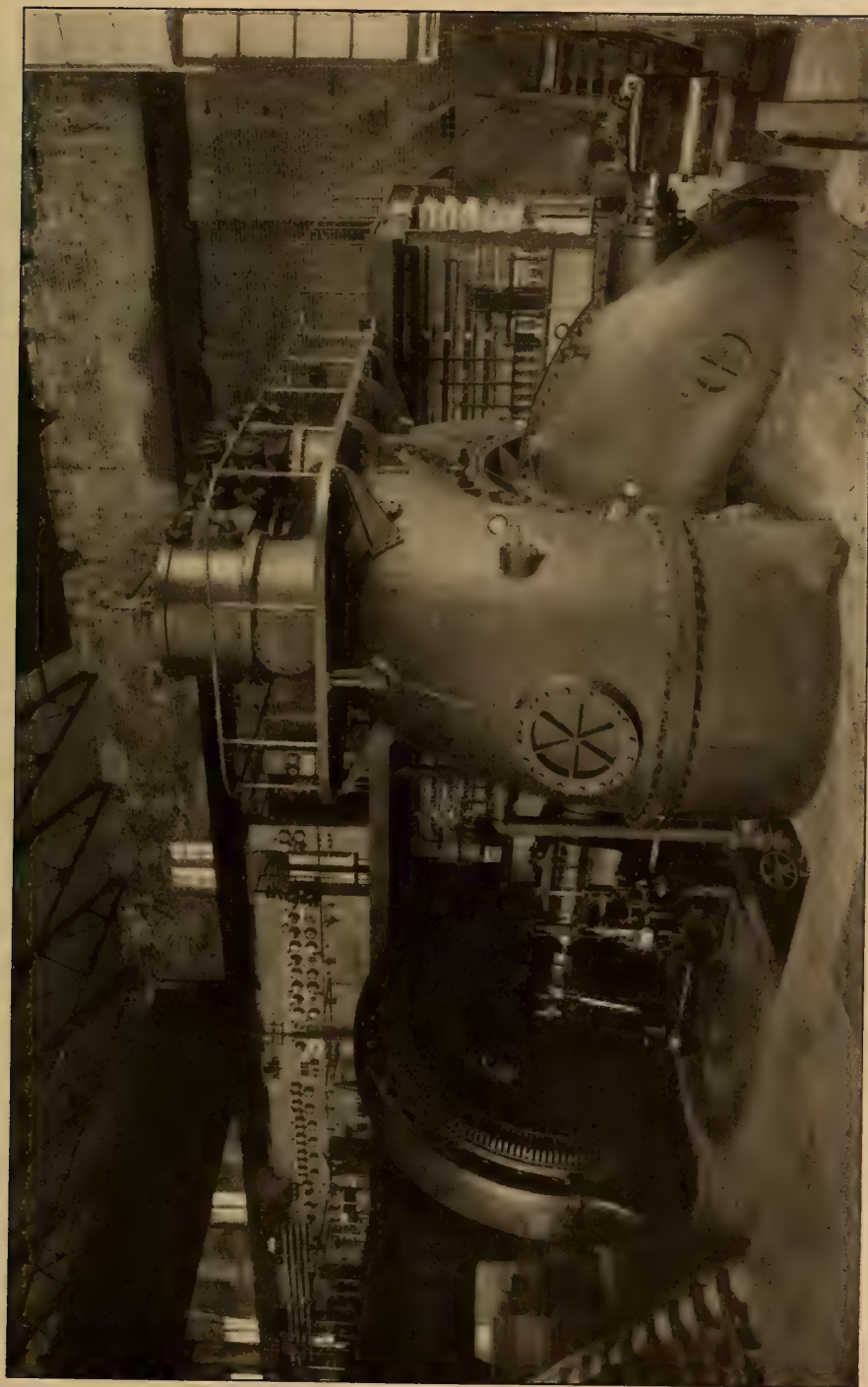


FIG. 6.—EXTERIOR VIEW OF UNIT NO. 4, WATER WHEEL AND CONNECTED GENERATOR

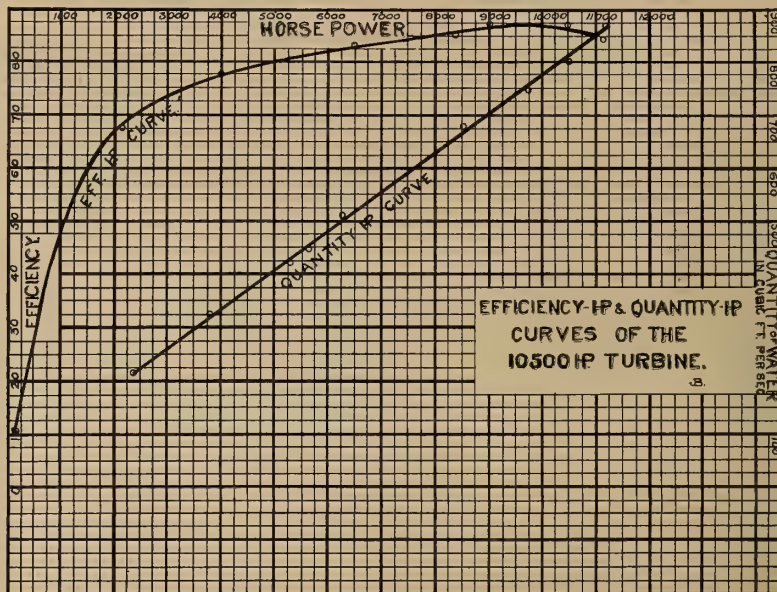


FIG. 8.—DIAGRAM OF TURBINE TEST

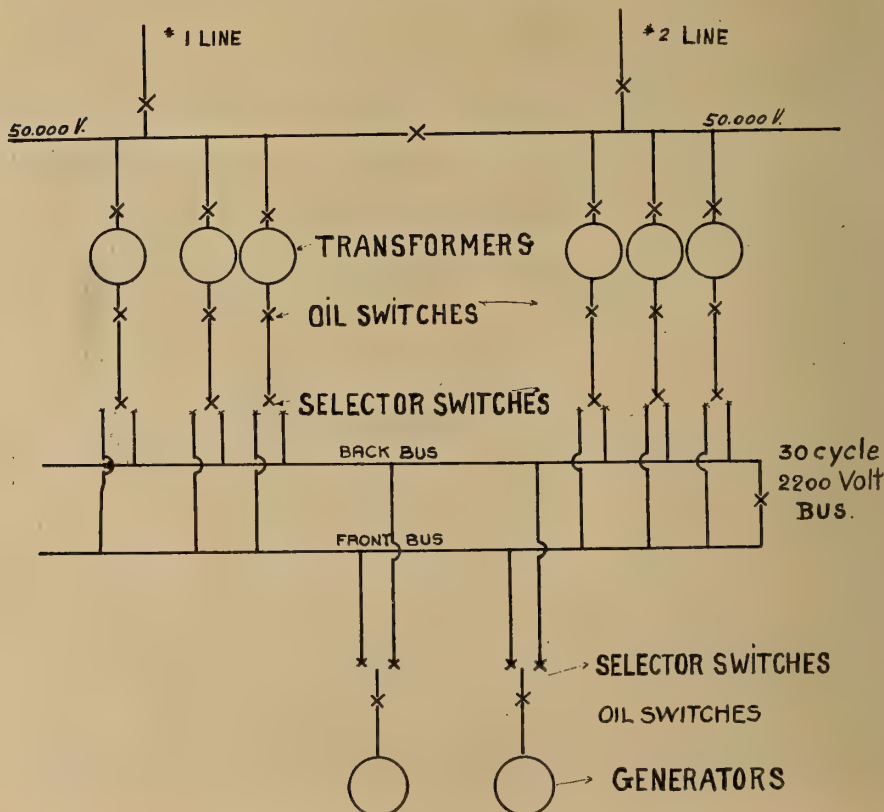


FIG. 9.—ARRANGEMENT OF BUS BARS AT THE SHAWINIGAN STATION



FIG. 10.—THE NEW TRANSMISSION LINE FROM SHAWINIGAN FALLS TO MONTREAL

type approaching it in magnitude had ever been designed. The results as to efficiency have never, to the writer's knowledge, been exceeded by a water wheel at any time, and are in the highest degree creditable to the constructing firm and its engineer.

Fig. 5 shows a general view of the penstock, and a view of the unfinished end of the power house and transformer house, which had been temporarily closed with wood with a view to further extension. Also the general tail race and discharge from the several wheels.

Fig. 6 shows a general view of the water wheel and connecting generator-forming unit No. 4. In Fig. 6 the bus-bar and switching device is seen in the background, as well as the switchboard on the gallery floor above the bus-bars. The gallery built on to the wheel case is on the same level with the switchboard gallery

floor, and gives access to the gate-operating mechanism.

The wheel gates are of the shutter type, twenty-four in number and 24 inches wide. The gates are connected by forged-steel links on each side to a pair of steel rings, which, by means of rods, are connected to pistons, and an exterior view of the cylinders for which is seen in Fig. 6. The pistons, with their attached mechanism, are in duplicate and may be used together or separately, as each piston has sufficient power to operate the gates. The pistons are controlled by the centrifugal governor, shown in Fig. 6, standing on the floor between the water wheel and the generator. If desired, the governor can be cut out of action at any time, and the gates operated by hand valves, situated on the gallery.

The switchboard is shown more in detail in Fig. 14. The generator panel for this fourth unit being the



FIG. 11.—VIEW IN THE MONTREAL SUB-STATION

right-hand panel in the picture. The opening between this panel and the next one to the left gives access to the transformer room. Next, on the left, are the three generator panels controlling the three generators previously installed. The next two panels are the exciter panels. The next is the station panel, and to the left are the various transformer and feeder panels.

Fig. 7 shows in detail the bus-bar arrangement underneath the switch-board gallery. The bus-bar system is a simple one. There are two main bus-bars, called the "front" bus and the "back" bus.

These bus-bars can be connected in parallel by an oil-switch. Each generator feeds through its own oil-switch and then through knife-blade selector switches, to either or both bus-bars. From the bus the power

is taken through selector switches to the feeder oil-switches and then to the transformers or other circuits. The plan eventually is to sub-divide each of these bus-bars and approach a unit system by which each generator can be loaded up independently of the others, should occasion arise.

The bus-bars, oil-switches, cables, and so forth, are all protected by brick and concrete partitions. The whole arrangement is designed to reduce to a minimum the danger of damage by reason of short circuits. The row of electrically operated switches seen in the left of Fig. 7 are the generator switches. Each of these switches is set as nearly back of its own generator as practicable, and connects to the generator by means of lead cable, laid in covered ducts in the power-house floor. From these switches lead-covered

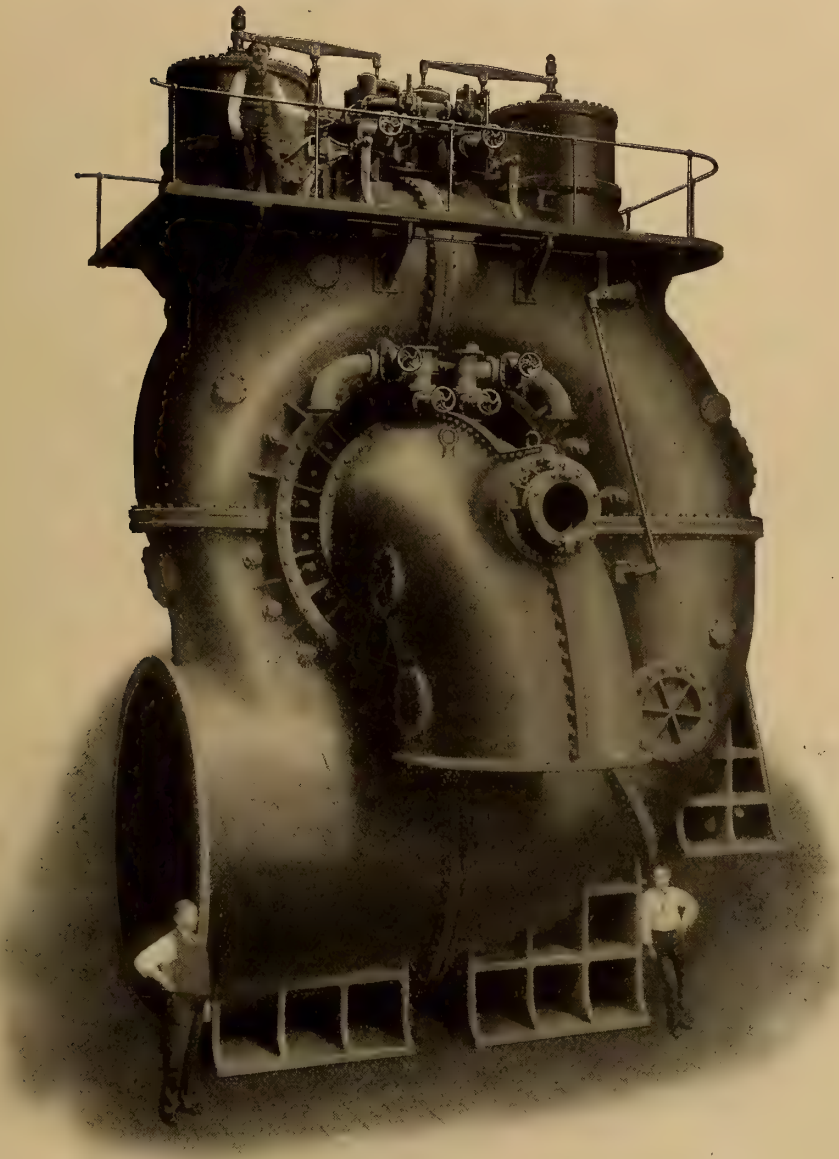


FIG. 12.—THE 10,500-HORSE POWER TURBINE. BUILT BY THE I. P. MORRIS CO., PHILADELPHIA

cables pass underneath the floor between the switches, and the buses to the knife switches by which they may be connected to either set of bus-bars.

The current is conducted from the transformer switches through lead-covered cables to the low-tension side

of the step-up transformers. These transformers, and their arrangement of installation in transformer house, were fully described by Mr. Mershon in the article above referred to. The original plan was to install the transformers on one side of the transformer house only. A plan of high-



FIG. 13.—GAUGING THE FLOW OF WATER BY THE PITOT TUBE

tension wiring was worked out by Mr. John A. Walls, assistant engineer, and Mr. Julian C. Smith, superintendent of the Shawinigan Water & Power company, by which the installation of the second row of transformers was made practicable, this arrangement of the transformers and the wiring including the connection to the static interrupters, the lightning arresters, and the method of connection to the high-tension line. This same arrangement of

transformers and connections were also adopted for the Montreal sub-station. In the Montreal sub-station the conditions to be met required two sets of 60-cycle bus-bars and one direct-current bus-bar for the rotary converters. To meet these conditions and to aid in making the system flexible and less liable to total interruption, the 30-cycle bus-bar system is so arranged that it can be divided into three parts to feed, respectively:

(1) One-half of the frequency changers.

(2) The other half of the frequency changers.

(3) The rotary converters.

The system is further arranged so that all the load can be carried on either of the two transmission lines, or on both, or the lines can be separated and a portion of the load carried on each line, which lines might be fed from separate bus-bars and separate generators at Shawinigan should the necessity arise.

The bus-bar and switching arrangement for both the Shawinigan and the Montreal stations were worked out by Mr. Walls and Mr. Smith. In connection with the addition to the Montreal sub-stations the 4000-KW. motor generator set which has been installed in the Montreal sub-station is of special interest on account of its size. This machine consists of a 60-cycle, three-phase, 2300-volt generator, direct-connected to a 30-cycle, three-phase, 2400-volt motor. The generator is rated at 4000 KW. at 75 per cent. power factor, or a builder's rating of 5300 KW., or about 7100 H. P.

The rating of the motor to drive this generator is 8000 H. P., making by far the largest synchron-

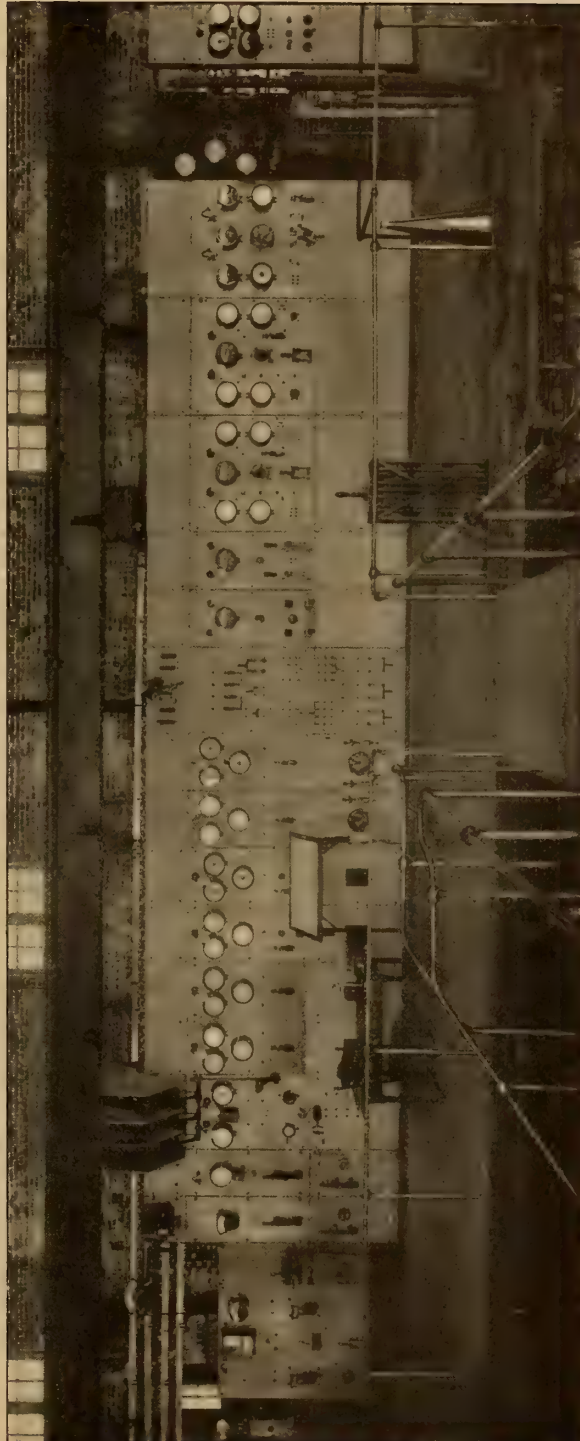


FIG. 14.—GENERAL VIEW OF SWITCHBOARD AT THE SHAWINIGAN FALLS STATION



FIG. 15.—GENERAL VIEW OF MEASURING APPARATUS AND PENSTOCK

ous motor in operation. To bring this set up to synchronous speed a direct-connected induction motor is used, which has two poles less than the synchronous apparatus. This induction motor is designed to give a large starting torque, and under test has developed 1500 K. V. A.

The speed of the induction motor is controlled by a motor-driven water rheostat, the motor being of the "open" secondary type. This scheme has

worked well in practice, the set can be brought from rest to synchronous speed, the switches closed, the field put on the generator, and the 60-cycle side connected to the bus-bar in 4 minutes. The machine runs at 300 revolutions per minute, which gives a peripheral velocity of over 10,000 feet per minute. In order to take care of the stresses set up by the centrifugal force, the manufacturers, the Allis-Chalmers-Bullock



FIG. 16.—VIEW OF PENSTOCK, SHOWING SUPPORTING SADDLES AND FOUNDATIONS

Company adopted the practice now much used in turbo-generator construction of building up the rotor of high-grade steel plates. This frequency changer has been in constant service for nearly two years, and no troubles of any kind have developed.

In the construction of the second

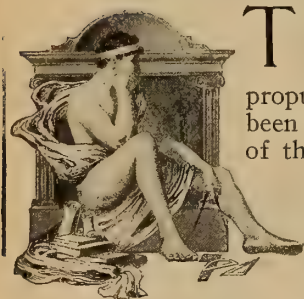
transmission line, the plans made by Mr. Mershon for the first transformer line were closely followed.

Fig. 10 is a view of a typical section of this line. The conductors were aluminum cables made up of seven strands of No. 7 wire, similar to the original line.

THE GAS TURBINE FOR AUTOMOBILE PROPULSION

By W. H. Stuart-Garnett

In the January issue of this magazine the definite progress which has been made toward the realization of a practical combustion turbine was shown, and the possibilities of such machines are becoming apparent to such a degree that their applications to different departments of engineering are already being considered. Although Mr. Stuart-Garnett does not consider specifically the gas turbine of Armengaud and Lemale, but treats the subject broadly, he makes no question about the mechanical possibilities of the combustion turbine in a variety of forms, and shows the especial adaptability of such machines to the important field of automobile propulsion. It must be remembered that actual thermal efficiency is only one of the elements to be considered in a motor for this service, and that all the qualifications must be taken into account. It is believed that this discussion will bring out the essential features of the subject, and that this important department of engineering will be found ready to use the gas turbine as soon as the constructive problems have been successfully solved.—The Editor.



THE application of the turbine to purposes of vehicular propulsion has always been looked upon as one of the possibilities of the future, but little serious attention has been devoted to the matter up to the present, by reason of the great and obvious mechanical difficulties in the way. The introduction of the gearless motor car seems, however, to be a first step in the right direction. The great momentum of a turbine rotor when running at full speed—and it will run efficiently under no other conditions—necessarily involves a great deal of wear on any friction clutch or gear-changing device interposed between the driving and following parts. The smallness of the starting torque in most types of turbine, on the other hand, make some form of gear-changer necessary, while the high speed of the turbine renders it unsuitable for any form of mechanical connection with the driving shaft of a car.

All these difficulties will, however, disappear if it should prove feasible, as now proposed, to drive the car by an electric motor deriving its power from a dynamo, itself carried on the chassis. With such a device, the relation between the speed of the car and that of the engine is exceedingly

elastic, and in fact the car may be manoeuvred to any extent without the slightest variation in the revolutions of the dynamo. A large starting torque, or a slow speed of running can be secured with perfect efficiency by a system of control acting only on the field magnets of the dynamo, and the arrangement can obviously be applied to a turbine running at 3000 or even 5000 revolutions with as much ease as to a petrol motor developing 900 revolutions per minute. At the same time, there are great obstacles still to be faced, and these have not, up to the present, been attacked in such a way as to hold out any great hope of their speedy subjugation.

So far as the steam turbine is concerned, it may be at once admitted that, failing some startling improvement in the economy of the non-condensing turbines, the impossibility of securing in a car or locomotive condensation with anything like an effective vacuum puts this engine out of court for purpose of land transit. It is only by reason of the far greater expansion obtainable in the turbine cylinder than in that of the reciprocating engine that the new form of prime mover has now surpassed the older one in efficiency. The performance of the non-condensing steam turbine cannot at present compare with that of the reciprocating engine operating under the same conditions.

Since in the case of internal com-

bustion engines condensation is clearly impossible, it has been contended that the internal combustion turbine cannot be expected, even if the difficulties of construction should be overcome, to show so high an efficiency as the gas or oil engine of to-day. But it must be remembered that in these engines release occurs at a moment when the cylinder pressure is very considerably above that of the atmosphere, and there is no reason why the internal combustion turbine should not expand the working gases usefully to atmospheric pressure, maintaining over the reciprocating engine precisely the same advantage as is enjoyed by the steam turbine over its competitor.

The practical difficulties in the way of a successful internal combustion turbine are due, in the first place, to the destruction of the turbine blades by the hot gases at admission, and, in the second, to the necessity of furnishing a suitable compressor and explosion chamber by means of which the working fluid may be supplied to the turbine cylinder. It is the object of this paper to suggest some lines along which the remedy for these evils may be sought.

Corrosion of the high pressure blades by the hot products of combustion has long been regarded by engineers as the chief obstacle on this line of development, and many methods of dealing with it have been suggested. One that deserves particular mention is the subject of a patent taken out by the British Thomson-Houston Company. According to this device, the gases are to be cooled by a water jacket during their passage through a nozzle of peculiar design, intermediate between the combustion chamber and the working cylinder. It is hoped that by cooling the gases during their retardation in a converging funnel it may be possible to secure their automatic compression to a higher pressure than that from which they were originally expanded.

The system is, of course, open to

the objection that the time of passage through such a nozzle is exceedingly short, and consequently the cooling effect of the jacket cannot in any case be very great. Further, all heat passing through the walls of the nozzle, from the working fluid to the water jacket, is necessarily lost to the engine, so that the efficiency of the device is essentially imperfect.

The Brush Company, of America, have devoted some attention to the use of a mixture of steam and gas formed by evaporating water in a separate boiler by the heat of the exhaust gases, and injecting the steam so formed into the mixing chamber. Now, a very great deal of steam will be required to produce sufficient cooling of the burned gases, and this steam must of course be formed at a pressure higher than that existing in the mixing chamber. It is clear, then, that a great deal of heat must go into the auxiliary boiler. At the same time, the working gases are cooled before use, and it is not obvious that the temperature of the exhaust will be very much higher than that of the steam to be supplied. So far, therefore, it does not seem to be established that the heat of the exhaust gases is, by itself, sufficient to generate the necessary quantity of steam, and the introduction of a separate furnace, particularly in a mobile turbine, is greatly to be deplored. The thought naturally arises that the evaporation might better be effected by means of the very hot gases before admission, the exhaust gases serving the purpose of a feed-water heater, but the thermodynamic effect of this operation we will consider more fully at a later stage.

A similar device is the subject of a recent British patent; but according to this latter system the steam and gas are not mixed but are projected through separate nozzles on to the bucket of an impulse wheel, so that these buckets pass through rapid alternations of temperature. What will be the effect of this action on their life is at present impossible to fore-

see. Clearly, the efficiency of this system depends on the practicability of preserving the absolute separation between gas and steam during and after the passage through the turbine, in order that the steam may be condensed, and the exhaust gases used for its re-evaporation. Considerable difficulty will necessarily be met with in securing this separation, and the resulting cycle of pressures in the wheel channels will be exceedingly bizarre, and only attainable by the reduction of all clearances almost to vanishing point. If, however, it should prove possible to effect this end, and if the durability of the buckets should prove satisfactory, the thermodynamic efficiency of this engine, working between the very different temperatures of the admitted gas and the exhaust steam, should be very high indeed, and there is no doubt, in this case, a future before the turbine.

All these systems depend upon the introduction of inert gas or steam into the live gases before admission to the cylinder, and in many cases this steam is produced by the heat of the exhaust gases. Curiously enough, it appears that the effect of generating the steam by the heat of the live gases does not appear to have been seriously investigated. For this purpose a combination of the Brush and the British Thomson-Houston systems may be adopted. Whereas the former injects steam into the live gases, and the latter "surface cools" them by water at the same stage, we may inject the water instead into the products of combustion. By this means no heat is lost to the engine, as in the British Thomson-Houston system; the device amounts, in fact, to the introduction of a boiler of perfect efficiency between the combustion chamber and the turbine, which is differentiated from the steam turbine by the fact that both steam and furnace gases are used as the working fluid, making it a mixed turbine.

The heterogeneous constitution of this fluid, of course, renders condensation impossible, but since the boiler

here is one of perfect efficiency (whereas the performance of the Lancashire boiler is never more than 70 per cent.), it does not necessarily follow that the use of steam only, in the resulting prime mover, is uneconomical.

The actual loss of energy in the high pressure gases, due to the injection of cooling water, may be readily determined, and for the purpose of this investigation we shall assume a solution of the compression problem, resulting in the production of burned gases at a pressure of 210 pounds, and a temperature of 2000 degrees F. It may be premised that every increase in the pressure of these gases results in a corresponding improvement in the efficiency of the action.

We are probably not far wrong in assuming, on the strength of Professor Hopkinson's recent experiments, that the specific heat at constant pressure of burned gases formed by the combustion of 1 pound of oil in 32 pounds of air will be approximately .307. The volume of the resulting mixture at the temperature and pressure above stated will be nearly 140 cubic feet. Into this gas, then, let us inject 12 pounds of water previously heated by the exhaust to a temperature of 250 degrees F. The effect of the evaporation of this water and superheating of the resulting steam will be to bring the whole mixture to the temperature of 700 degrees F., at which it can be used in the turbine without the slightest danger or detriment to the blades or buckets.

Now this drop in temperature will be accompanied by a reduction in the volume of gas from 140 to about 67 cubic feet; but at the same time there has been formed 12 pounds of superheated steam, occupying some 36 cubic feet, so that the actual decrease in the volume of working fluid is from 140 to 103 cubic feet, or 26½ per cent. And even this 26½ per cent. is not in fact lost to the turbine, firstly because the energy carried off by the exhaust gases is more than

correspondingly reduced, and secondly because the density of the working fluid is very nearly doubled in the mixing chamber, and this, in a turbine, is a matter of the utmost importance.

The reason that the steam turbine has been half a century behind the water turbine in its development is to be found in the rarity of the working fluid. The velocities of the expanding steam were too large for the most economical use to be made of them in an engine of this type, and it is still impossible to run the working parts of a steam turbine at such a speed as will really do justice to the energy of the working steam. This difficulty will necessarily be experienced in an even greater degree in the internal combustion turbine, and one of the greatest advantages to be derived from the water jet will be the increase in density of the working gases and the consequent reduction of fluid velocities in the turbine cylinder.

So far, then, as corrosion of the high pressure blades is concerned, it may be fairly said that the development of the internal combustion turbine for commercial purposes, and more particularly for purposes of transit, need no longer be regarded as millennial. The other difficulties, those connected with the compression and explosion of the unburned gases, are not yet completely overcome, but the subject is now receiving a great deal of attention, and some of the lines along which the solution is being sought bid fair to lead to a satisfactory result.

There are in actual use in internal combustion engines only two alternative thermodynamic cycles, although there is apparently no reason why an engine should not be designed for any cycle intermediate between them. These two are differentiated by the conditions under which combustion takes place, whether slowly and at constant pressure as in the Diesel motor, or rapidly and at constant volume as in the explosive internal com-

bustion engine, running with the spark timed for ignition at or near the dead point. The boundary between explosion and slow combustion is not, however, very definite, and it is of course clear that even in the petrol motor or gas engine combustion occupies an appreciable time, and the volume is not necessarily constant throughout the interval. In the case of a car running down hill, with a weak mixture and a late spark, the cycle actually approaches more nearly to that of the Diesel engine than to the normal Otto cycle of the petrol motor.

It is a curious thing that, of these two cycles, no attempts have been made to apply the latter to the internal combustion turbine, while the patents of Ferranti, Fullager, and others bear testimony to the skill and science devoted to the adaption of the Diesel cycle.

There is a great deal to be said for slow combustion. It not only gives a smoother action than that of the explosive engine and a more satisfactory indicator diagram, but, at least where compounding is used, a higher total efficiency. On the other hand, it necessitates a very much higher compression before ignition than does the other cycle, simply because there is little or no rise in pressure afterwards. Now this does not much matter in a reciprocating engine. The pressure in the cylinder may be raised to any desired amount by merely reducing the clearance. But when we come to the case of turbines the whole problem is changed, for at the very outset we are faced by the difficulty of securing adequate compression.

We have to decide first of all whether a rotary or reciprocating compressor is to be used; and it may be at once admitted that it is not at present possible to attain a high degree of compression at all economically with a turbo-blower. If, then, the Diesel cycle is used, it becomes necessary either to effect the whole compression by means of a reciprocating

cating pump, or else to use, as Ferranti has suggested, a turbo-blower for the first stage and an air pump for the second.

But if once the reciprocating piston is introduced into the mechanism, and the gases are compressed behind it at one end of the cylinder, we may as well explode them in situ, and revert at once to the reciprocating engine; or we may use the turbine as a sort of low pressure cylinder to such an engine and create a new mechanical hermaphrodite, consisting of a high pressure reciprocating internal combustion engine, sandwiched between a low pressure turbine and a directly coupled blower.

Such an engine may prove to have excellent features, but it is some distance off the track of our present investigation. Assuming, then, that reciprocating parts are undesirable, we are faced by the necessity of abandoning the Diesel cycle in favour of one in which gas or vapour is exploded in a closed chamber. It has been found possible to attain a pressure of 30 pounds in a Parsons turbo-blower with very reasonable economy. If gases so compressed are discharged into a closed chamber and there exploded, a pressure of about 200 pounds will be obtained and the products of combustion can be very effectively used in a properly designed turbine.

The trouble with such an explosion chamber is that it must be exhausted almost to atmospheric pressure before being put in communication with the compressor for a second cycle. Now the Parsons governor has proved that gust admission is satisfactory so long as the admission port is rapidly opened and closed; it will be very much the reverse if the pressure at admission is allowed to tail off slowly to 20 pounds or so before cut-off takes place. What, then, is to be done with the working fluid remaining in the combustion chamber when the pressure there has dropped (say) to 100 pounds? The compound reciprocating engine affords

the best guide in this matter. There the high pressure steam works in one cylinder until a certain amount of its energy is exhausted; it is then transferred to a second, where the expansion is continued or completed. The pressure in the first cylinder varies between the limits of, say, 200 pounds and 50 pounds, and in the second, failing a condenser, between 50 pounds and zero.

Suppose that we apply the same principle to a turbine of the Parsons, Curtis, or A. E. G. type, one that has several stages with intermediate chambers. When the combustion chamber can be connected to one stage chamber after another, and, as it is cut off from each, another combustion chamber may be connected. A two-stage turbine would then have three combustion chambers of which at any given moment one would be connected to the blower, one to the high pressure end of the turbine case, and one to the intermediate stage chamber. The pressure in the turbine case would of course oscillate with every explosion, but the more numerous the chambers, the smaller would be the oscillations, exactly as in the multiple expansion reciprocating engine.

The internal combustion turbine here shadowed forth is not, it must be confessed, a simple one; indeed, it is only reasonable to contend that an engine involving the complex connections and valves required for the operation of this turbine can never be applied successfully to purposes of locomotive traction. At the same time it is possible that a producer gas turbine constructed on these lines may be found applicable to purposes of stationary power generation on a large scale. But on the other hand, for a motor of small power there is another possible system which, though it furnishes no solution of the problem of designing a new prime mover, may yet prove valuable where the cost of fuel is not an important consideration.

Three or four years ago Ferranti

suggested the use of liquid air or oxygen as the medium of combustion in a small turbine or other engine for the propulsion of torpedoes or other similar purposes, and the recent application of regenerative cooling to the production of these liquids has, by diminishing their cost, actually made this use of them a commercial possibility. An engine using liquid air in this fashion is only partially a prime mover, since a part of the energy developed in the motor is stored in the air by the original compressor. But it is likely that a tank of liquid air may shortly prove a more economical, as well as a far more portable, store of energy than a battery of accumulators.

In an automobile run on this principle, the liquid in actual use would be carried in a container at high pressure under a safety valve. From this container it would pass through a

throttle into the evaporator, and be there not only evaporated by contact with the exhaust gases, but, if necessary, superheated before admission to the combustion chamber. The supply of fuel would also be effected by air pressure, and the engine would run smoothly and continuously on the Diesel cycle. The temperature of the working gases might be sufficiently controlled by means of the air throttle.

Probably the application of the turbine to purposes of vehicular propulsion will be first effected by some such device as this, but the larger problem of utilization of the gas turbine in great commercial undertakings calls for a different solution, and that cannot be considered a real settlement of the compression difficulty which consists simply in getting it done at the garage instead of being effected by a part of the mechanism.



THE PRESENT STATUS OF THE ART OF WATER SOFTENING

By George C. Whipple



HARD waters have always been considered objectionable for common use. Universal experience is summed up in the apologetic qualification heard so often, "We have good water here, but it is hard." In recent years the economic importance of hard waters has been lost sight of to a considerable extent in view of the greater prominence of sanitary matters. Engineers and manufacturers are now studying the subject anew, and the more it is studied the greater its importance becomes apparent. It is seen that in some industries the difference between a hard water and a soft water may mean the difference between loss and profit on the balance sheet; in others it may mean a change of the location of a factory; it may mean a difference in the quality of the manufactured product or the success or failure of some chemical process; it may mean changes in labour, in rates of transportation, in railroad

time table schedules; it may mean accidents, attended with loss of property and even of human lives.

The term "hard water" should be strictly applied to waters which contain salts of calcium and magnesium, particularly their carbonates and sulphates, but in popular and local parlance it is frequently, though erroneously, applied to waters which contain other substances, such as iron, sodium chloride, and even free acids or alkalies. In studying the subject in its general aspect it seems best to include these other mineral constituents which have a bearing on the problem.

Hard water is unsatisfactory for household use for several reasons.

It wastes soap and is therefore a source of expense. The writer once made a series of experiments to determine the effect of various degrees of hardness on the amount of soap used in washing the hands, in bathing, and in general household uses. Various kinds of soap were used, and it was found that 1 pound of the average soap would soften 167 gallons of water which had a hardness of 20 parts per million. This was equivalent to about 3 tons of soap per million gallons, which, as a cost of 5 cents per pound, would amount to \$300 per million gallons. It was found also that for every increase of one part per million of hardness the cost of soap increased about \$10 per million gallons of water softened, or 1 cent per 1000 gallons.

All of the water used by a community is not completely softened. The number of gallons per capita per day completely softened by soap has been estimated by different authori-



KENNICOTT WATER-SOFTENING PLANT ON THE PITTSBURG & LAKE ERIE R.R. AT MCKEES ROCKS, PA.
CAPACITY, 60,000 GALLONS PER HOUR

ties all the way from 1 to 10. It would certainly be a conservative estimate to assume it as 1 gallon. On this basis the additional cost of soap in a household would be 3.65 mills per year per person for each part per million of hardness, or, roughly, 2 cents per year for a family of five. This seems like a small amount, yet in a place where the hardness of the water is 250 parts per million—a figure not at all uncommon in some Western States—it would amount to \$1 per capita per year.

When the new water supplies available for the city of New York were being considered by the Burr-Hering-Freeman Commission in 1903, it was estimated that the soft water of the Esopus creek was worth \$330,000 a year more to the people of Manhattan than the hard waters of the streams east of the Hudson River.

Hard waters are disagreeable to wash with. The calcium and mag-

nesium stearates, which are precipitated by soap, give rise to unsightly scums in a wash bowl or bath tub. They tend to fill the pores of the skin, causing the hands to chap.

It is in the laundry that the effects of hard water are most noticeable. Not only are large amounts of soap required to produce a lather, but the stearates above mentioned settle on the clothes, fill the pores, and tend to rot them and make them look dingy. Hard waters also encourage the use of strong soaps, washing compounds, etc., which may contain ingredients destructive of the fabrics.

In culinary operations, such as in making tea, hard waters are less satisfactory than soft waters. This is a fact which few housekeepers do not fully realize, but which may be easily demonstrated by experiment.

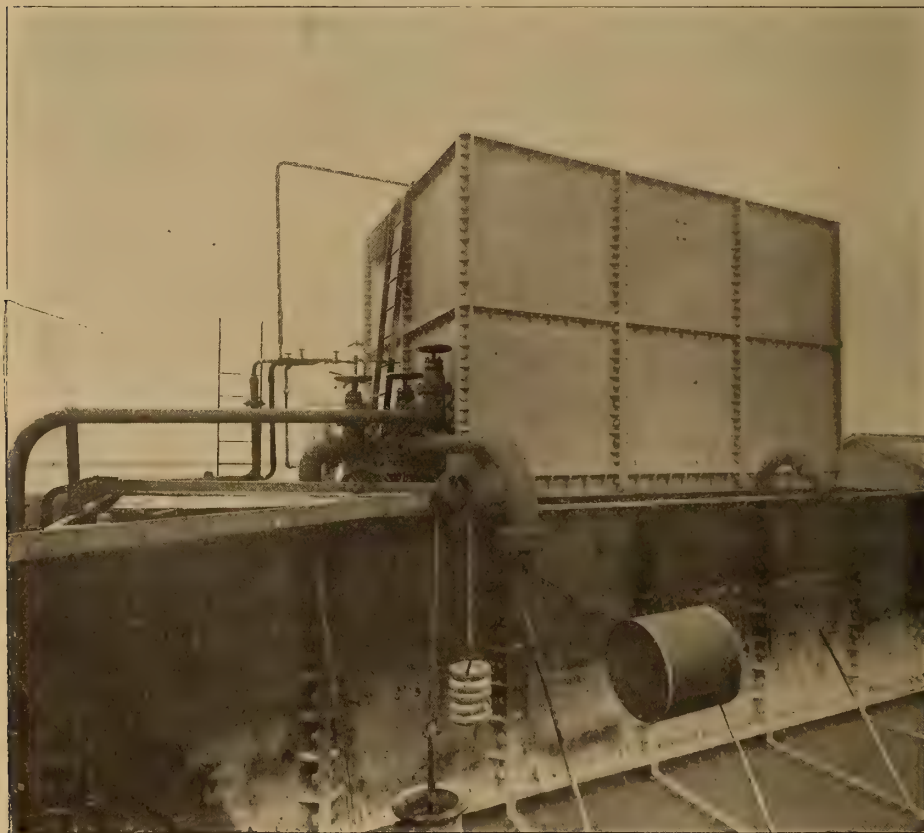
The physiological effects of hard water, so far as known, are insignificant; and most of the theories

which have been advanced to show the great danger of drinking distilled water, or, on the other hand, the evil effects produced by drinking water containing salts of lime, are without substantial foundation.

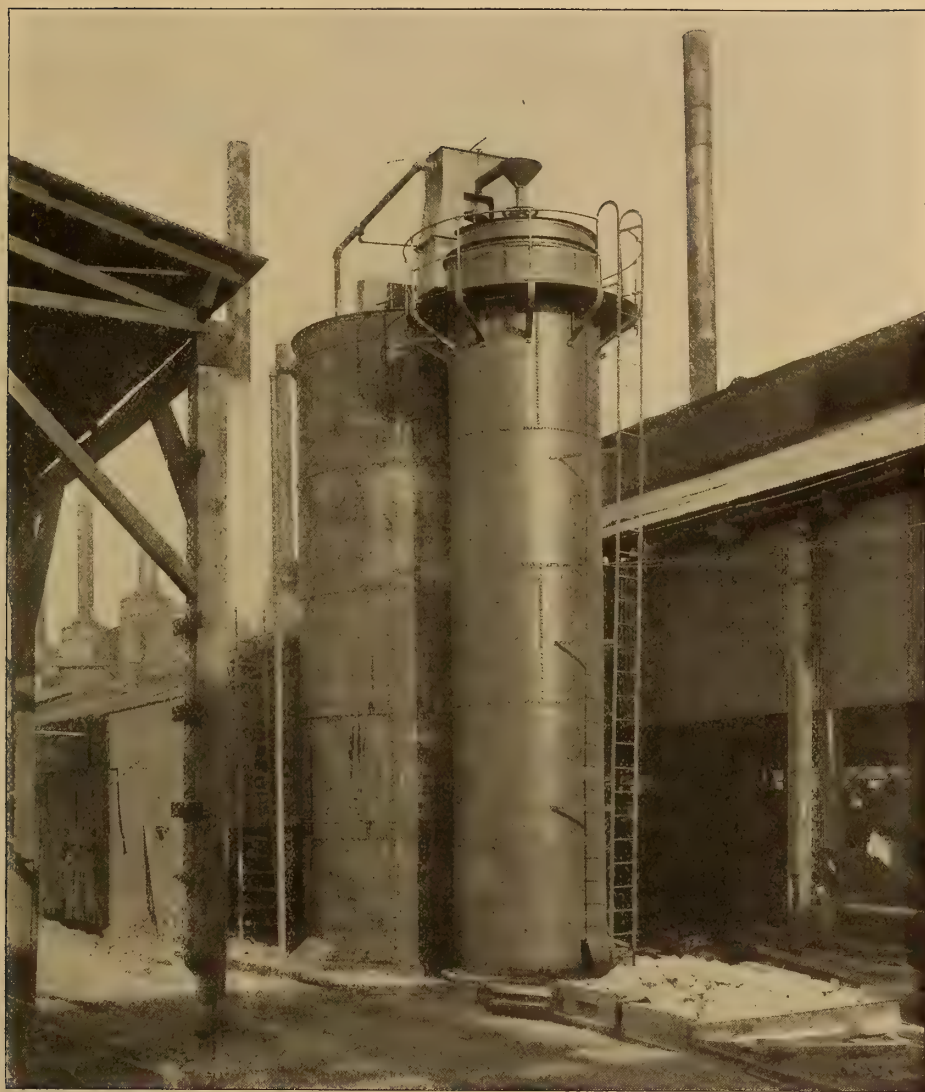
In almost every instance where chemical manufacturing processes involve the use of water its hardness affects the result. The effect may be an economic one and cause merely a waste of material; but it may be a vital one and influence the entire process. As illustrations, the operations of bleaching and dyeing, tanning, sugar refining, and paper making may be mentioned.

Dyeing is a process which involves many very delicate reactions and in which immense quantities of water are used in mixing the colors and in

washing the goods. In dyeing silk, for instance, 1000 gallons of water are sometimes used for each pound of silk. Many aniline colors are said to dissolve badly in calcareous waters. The colors of cochineal, methyl blue, etc., are materially altered by the presence of hardening constituents, and as hard waters often fluctuate in hardness, the matching of delicate colours is a matter of difficulty. In madder dyeing, hard waters may not only cause changes of shade, but may cause precipitates to form in spots. In wool dyeing the effect of hard waters is noticeable. The fibres do not become well degreased and insoluble calcareous soaps deposit on the threads, so that they do not take the dye evenly. Ferruginous waters are, of course, highly objectionable,



GREAT NORTHERN RAILWAY OF IRELAND. ARCHBUTT-DEELEY SOFTENING PLANT FOR 33,600 GALLONS PER 24 HOURS. MATHER & PLATT, LTD., MANCHESTER



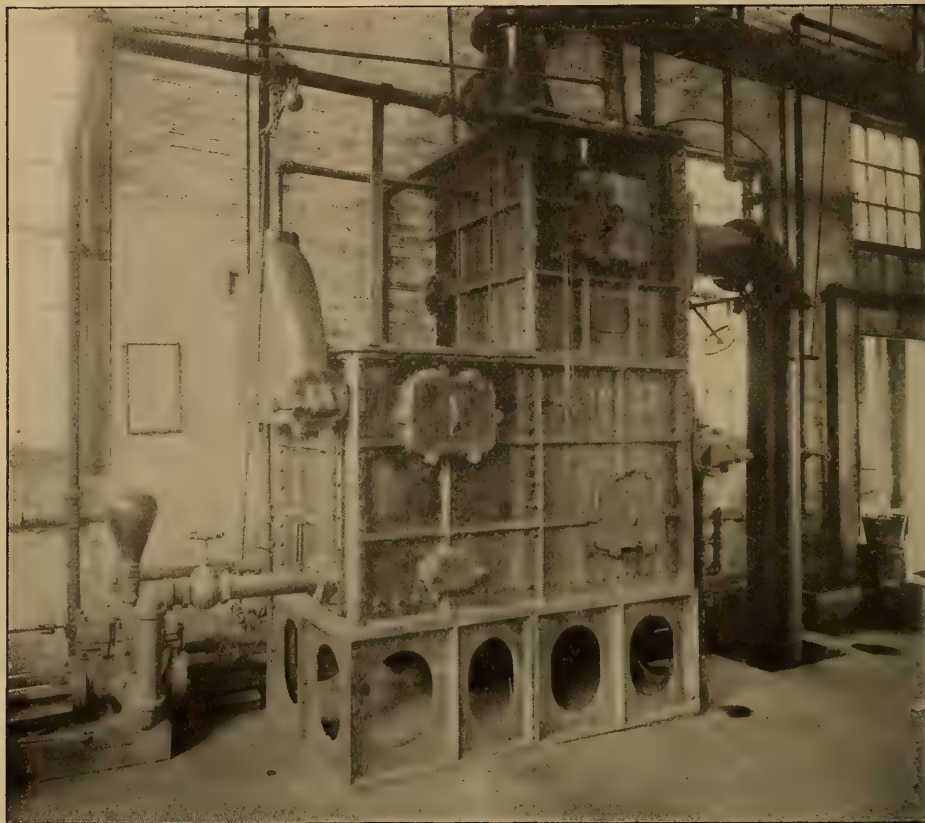
EUREKA WATER SOFTENING SYSTEM AS INSTALLED AT THE KNOXVILLE IRON CO., KNOXVILLE, TENN., FOR TREATING 10,700 GALLONS PER HOUR. DODGE MANUFACTURING CO. MISHAWAKA, INDIANA.

especially in white dyeing or bleaching.

Great quantities of water are used in tanning. The unhairing of the skin is done by loosening the roots of the hair by saponifying with quicklime the greasy matter secreted by the small hair glands. If the water contains a large amount of calcium carbonate, some of this is precipitated

on the dermal tissue. This deposit interferes with the absorption of the tannin in the cells of the hide and causes brown stains to appear on the leather.

Sugar refining requires pure water. It is used in filtering the syrups through animal charcoal. This charcoal has the power of absorbing the hardening constituents of water, and



SORGE-COCHRANE HEATER AND PURIFIER AT THE KINGSFORD FOUNDRY & MACHINE CO., OSWEGO, N. Y.
BUILT BY THE HARRISON SAFETY BOILER WORKS

if it does this to a considerable extent it quickly loses its bleaching power, which has to be restored by treatment with dilute hydrochloric acid. In manufacturing beet root sugar the phenomenon of osmosis comes into play between the water and the juice of the beet root, the cell walls playing the part of a dialyser. Hard waters are harmful in this operation, as they tend to cause an appreciable amount of sugar to be retained in the mother liquor. The lower the salts in solution the easier it is to eliminate the saline matter from the molasses and increase the yield of sugar.

Hard water is unsuited for paper making for several reasons. It interferes with the sizing used on the paper, and has an important effect on dyeing, as mentioned above. Iron

salts especially are objectionable in a paper mill. Under the influence of an alkali the iron is precipitated on the paper, giving rise to brown spots and streaks. Hardness affects the process of paper making in another way. The paper pulp is carried over sheets of wire gauze, and if lime is present in the water the pores of the wire gauze are likely to become choked up with what is called "water stone," which is really nothing else than calcium carbonate.

Many other industries might be mentioned in which hard waters play an important part, such, for instance, as the manufacture of soap, wool scouring, printing, brewing and distilling, photography, ice making, etc. It would be interesting if some industrial chemist would take up this matter and furnish data showing, in

dollars and cents, the effect which hard water has on these various manufacturing processes.

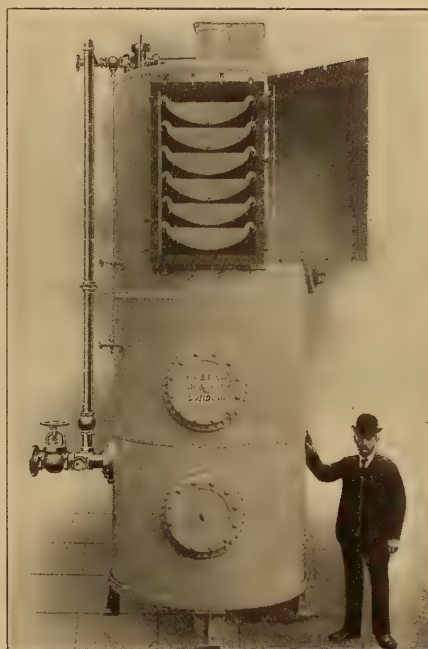
Steam users suffer more from the bad effects of hard waters than any one else, consequently the use of hard water in boilers requires more than a passing notice.

The economical operation of a boiler demands good water as much as it does good coal. This is better appreciated to-day than a few years ago. With the older boilers of small size and simple type, the character of the water was of less importance, but the present-day striving for economy in steam production, which has resulted in the use of so many auxiliary attachments to the modern boiler, requires that great care shall be given to the quality of the water used. Bad boiler waters may cause corrosion, scale, foaming, overheating, and leaks. These result in loss of heat, in increased labour of attendance, in greater expenses for operation and repairs, in a shortened life of the plant, and increased liability of explosion.

All natural waters are more or less corrosive on account of the presence of dissolved oxygen and carbonic acid, but waters which contain chlorides, nitrates, sulphides, etc., may, under certain conditions, become very corrosive. Swampy waters, and some driven well waters, usually contain more free carbonic acid than ordinary river waters. In some of the mining districts the only waters available are distinctly acid and are exceedingly corrosive. Magnesium chloride is corrosive, and that is largely why sea-water is so objectionable for use in boilers. It is often said that sodium chloride is not corrosive, but in the presence of silica it may become so. Waters which are naturally only slightly corrosive may become very much so if allowed to concentrate in the boiler, which they will do unless the boiler is occasionally emptied and cleaned. Corrosion is increased by mechanical action,—that is, by movements of the boiler sheet caused by

expansion and contraction. It is most likely to occur at points where there is a tendency to movement and also along the water line. Local corrosion is frequently referred to as "pitting" or "grooving." Occasionally galvanic action may cause corrosion.

The formation of boiler scale is due to the precipitation from the water of the carbonates and sulphates of calcium and magnesium, together with smaller amounts of other salts



EXHAUST STEAM HEATER AND PURIFIER. PATERSON ENGINEERING CO., LONDON

and of suspended matter. For each salt there are certain conditions which will cause precipitation. Calcium carbonate is quite insoluble after its extra molecule of carbonic acid has been driven off by heat. Calcium sulphate becomes almost insoluble above 250 degrees F. (120 degrees C.). Magnesium carbonate is changed to magnesium hydrate and precipitated. Boiler scale may also contain compounds of iron, silica, alumina, organic matter, etc., in endless variety of composition. Generally speaking, carbonate scales are soft and are more in the nature of a sludge, or



THE BRUNN-LOWENER WATER SOFTENER AS MADE BY LASSEN & HJORT, LONDON

mud, than true scale. Sulphates, on the other hand, form a hard scale, especially when mixed with magnesia and silica. Calcium sulphate precipitates in a compact crystalline form which can sometimes be removed only by hammering and chipping. It may happen that different kinds of scales occur in the same boiler, due to the different temperatures of the sheet in different parts and to the circulation of the water. The scale in the tubes is often different from that on the sheets.

Hard waters invariably form scale and comparatively soft waters may also do so if the boiler is used too long without being emptied. Concentrated soft waters are almost as bad in their effects as waters naturally hard. The greater the hardness, however, the more troublesome will the water be.

Foaming is caused chiefly by an

excess of alkaline salts which cause the water to form suds, as if soap had been added. This makes a boiler unmanageable and affects the quality of the steam.

If grease is present in the water the sludge or scale may become very sticky. In this condition it adheres tenaciously to the plates and causes over-heating, which usually occurs in spots. Scales themselves may cause the sheets to become over-heated. They may also give rise to unnatural movements of the shell through expansion and contraction, and may thus ultimately cause leaks.

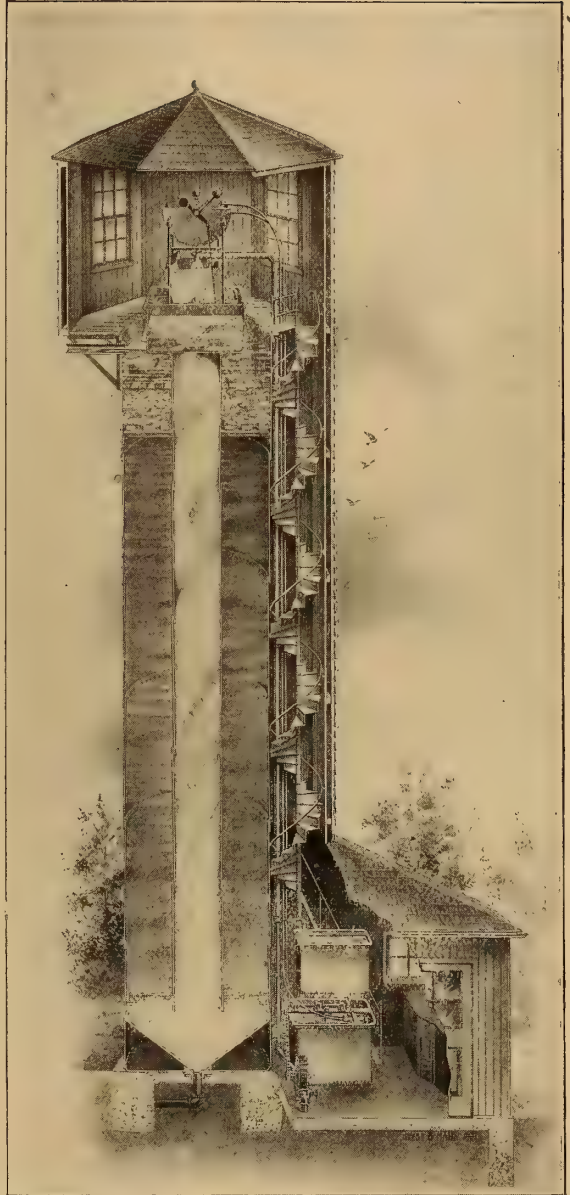
The care of a boiler has very much to do with the effects of hard waters. In fact, good care is a vital necessity even with the best of waters. By frequently emptying the boiler and cleaning it many of the objectionable effects above noted may be materially reduced. The frequent

THE ART OF WATER SOFTENING

blowing off of a boiler tends to reduce the amount of sludge, and to that extent it is advantageous, but in the process of blowing off only a small part of the water is removed. Many of the dissolved substances still remain. Much better results would be obtained by allowing the boiler to cool, emptying it and cleaning if necessary. Corrosion due to gases can be eliminated to some extent by allowing a thin scale to form in the boiler.

The use of boiler compounds is a remedy often resorted to and one which has its legitimate use; but, as a rule, proprietary boiler compounds are a delusion and a snare. In serious cases of acid corrosion lime or caustic soda may be used with advantage. Nothing will effectually prevent the precipitation of calcium carbonate, but the use of soda will cause some of the calcium sulphate to settle as carbonate instead of sulphate, thus making the character of the scale less objectionable. To prevent adherence of the scale to the boiler shell many substances have been used, such as potatoes, kerosene and all sorts of nostrums, organic and mineral. Most of these are practically worthless.

Of the boiler compounds more commonly sold none have given more general satisfaction than those which have soda and some form of tannic acid as primary constituents. Tannic acid has a slight action on the iron of the boiler, and is reasonably efficient in preventing scale from sticking, while if properly used its action on the iron is not serious. Such



AMERICAN BRUNN-LOWENER WATER SYSTEM AS INSTALLED FOR
RAILWAY WATER STATIONS. AMERICAN WATER
SOFTENER CO., PHILADELPHIA

boiler compounds are often sold for 50 cents to \$1 per gallon, but any engineer can easily make them at a cost of 15 cents per gallon by purchasing hemlock extract and soda ash and mixing them in a barrel in proper proportion. A convenient rule is to

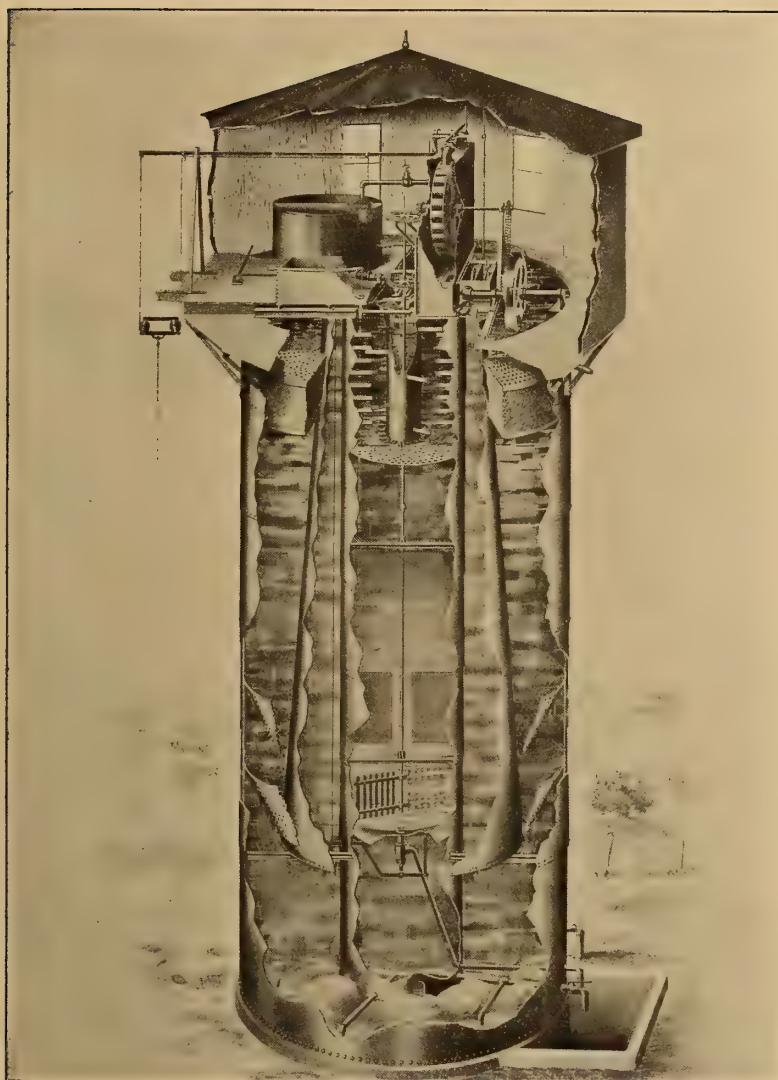


ELKHORN COAL & COKE CO., MAYBEURY, W. VA., KENNICOTT WATER SOFTENER FOR 10,000 GALLONS PER HOUR, FOR DOMESTIC PURPOSES AND BOILER FEEDING

mix one gallon of hemlock with two gallons of water and add three pounds of soda ash. Hemlock extract costs from 3 to 5 cents a pound in barrel lots, and soda ash costs about 2 cents per pound. The proportion and the quantity necessary to be used can be varied according to the character of the water. In most cases boiler compounds are improperly used and do but little good. Their indiscriminate use is wasteful and generally unsatisfactory. Nevertheless, they

may be made to perform certain legitimate functions. Their use needs guidance, not wholesale condemnation.

Another method often adopted to avoid the bad effects of hard waters is the use of feed-water heaters and purifiers. These are devices for precipitating the solids before the water reaches the boiler. In some cases they are serviceable, particularly when the hardness of the water is due to carbonates; but they are



SECTION OF KENNICOTT WATER SOFTENER

The reagents are added in the mixing chamber at the top, the water passing down the centre and up the annular space to the filter above. The precipitates are blown off from the bottom.

more or less troublesome, and the precipitation of the sludge in the heater tends to reduce the efficiency of the apparatus for its primary object, namely, that of heating the water. Generally speaking, it is preferable in the case of hard waters to carry on separately the operations of softening and heating the feed-water.

Many estimates have been made to show how much the steam maker loses by using a hard water instead of one satisfactory in character. Figures are often given showing the effect of boiler scales of different thickness on the loss of fuel. For example, it is sometimes stated that a boiler scale one-eighth inch thick will cause a loss of 20 per cent. in the

heat utilized from the fuel, while a scale three-eighths of an inch thick will cause a loss of 50 per cent. It is said that the resistance of sulphate scale to the passage of heat is from twenty to fifty times as great as that of an equal thickness of wrought iron, and that a film of grease one one-hundredth of an inch thick is equivalent in its heat resisting powers to a boiler scale one-tenth of an inch thick, or to a steel plate ten inches thick. Figures of this character cannot be considered as very accurate, as they are based on insufficient data,

ing table, based on a report of the Chicago & Northwestern Railway, is an excellent illustration of this. The figures show decided savings in coal, in labour and materials for repairs on engines, etc. One of the most important advantages to the road was the decrease in the number of engine failures. This means more to a railroad man than to an outsider, as it involves losses due to the stopping of many trains, the derangement of timetables, charges for perishable freight, overtime, etc. The committee on water service of the American Rail-

COMPARISON SHOWING THE EFFECT OF WATER SOFTENING AT SEVENTEEN STATIONS ON THE CHICAGO & NORTHWESTERN RAILROAD. (THE TWO YEARS REPRESENT THE CONDITION BEFORE AND AFTER SOFTENING)

	1902	1903
Ton mileage, in million ton-miles.....	2,934	3,154
Increase in ton-mileage		230 (7.5%)
Pounds of coal per 100 ton-miles.....	28.7	27.5
Saving in coal, pounds per 100 ton-miles.....		1.2
Saving in coal (at \$3 per ton for 3000 million ton-miles.....)		\$30,000
Average assignment of engines (83 per cent. of them were in constant service both years)	159	154
Saving in assignment of engines.....		5
Saving in engines (10 per cent. interest and depreciation) on cost of five engines at \$10,000 each		\$5,000
Number of boilermakers employed.....	36	23
Number of helpers employed.....	42	30
Total number of labourers on boilers.....	78	58
Saving in labourers		20 (26%)
Saving in wages of boilermakers and helpers.....		\$7,700
Saving in materials for boiler repairs.....	Not estimated, but known to be large	
Boiler failures from leaky flues.....	544	99
Boiler failures from leaky fire-boxes.....	33	20
Boiler failures from leaky arch tubes.....	6	1
Total	583	120
Reduction in number of boiler failures.....		463 (79%)
Estimated saving to the road, all causes.....		\$75,000

yet they serve to illustrate the fact that boiler scales do cause very material losses of heat. Other figures have been given to show the reduced life of boilers by reason of corrosion or the presence of scale, and, while too inaccurate to deserve quotation, they help to illustrate the same truth, that bad boiler waters cost money to the steam user.

The most accurate figures, perhaps, showing the excessive cost of hard waters as compared with soft waters, are those which have been compiled by some of the Western railroads. They are based upon data relating to the use of water in locomotives before and after the installation of water softening plants. The follow-

ing table, based on a report of the Chicago & Northwestern Railway, is an excellent illustration of this. The figures show decided savings in coal, in labour and materials for repairs on engines, etc. One of the most important advantages to the road was the decrease in the number of engine failures. This means more to a railroad man than to an outsider, as it involves losses due to the stopping of many trains, the derangement of timetables, charges for perishable freight, overtime, etc. The committee on water service of the American Rail-

way Engineering & Maintenance of

Way Association summed up the

benefits of the use of soft water to

railroads as follows:—

1. Fewer boiler failures due to

leaks.

2. Longer life of flues and fire-box

sheets.

3. Reduced cost of labour for re-

pairs and washing boilers.

4. Increased locomotive mileage be-

tween stoppings.

5. Increased ton mileage per pound

of coal consumed.

6. Decreased number of locomotives

in service.

7. Better feeling among the men,

due to fewer failures and shorter time

on the road.

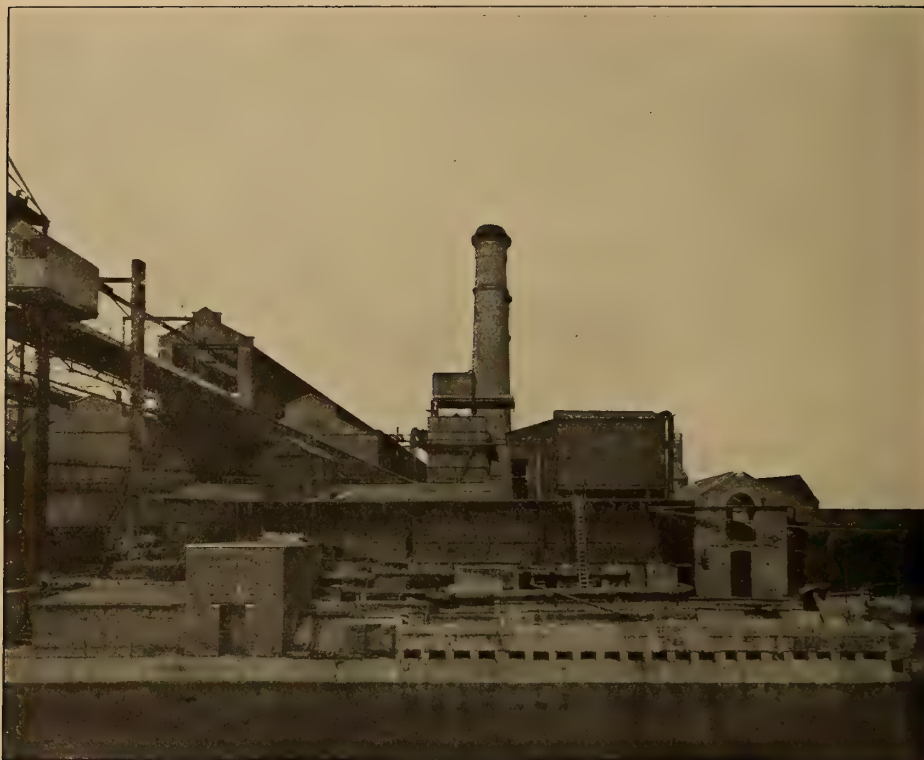


WATERING STATION ON THE VANDALIA R.R., INDIANAPOLIS, IND., EQUIPPED WITH KENNICOTT SOFTENER FOR 15,000 GALLONS PER HOUR

8. Less expense in cost of over-time and delayed time.

The point at which water becomes objectionally hard has never been exactly defined. Standards of hardness vary in different parts of the country. The ordinary person washing his hands considers the water soft if the soap will quickly produce a suds without curdling. A hardness of 10 parts per million is practically unnoticeable, and it requires a hardness of 20 or 30 parts per million to

produce "curdling." Waters which have a hardness below 25 parts per million seldom cause much complaint, but when the hardness rises above 50 the water is well entitled to the appellation "hard," and above 100 it may be called very hard. In some parts of the country hardnesses of 200 or 300 are observed; these may be termed "excessive." For the sake of having some standard by which to classify waters with respect to their hardness, the following figures may



METROPOLITAN ELECTRICITY SUPPLY WATER SOFTENING PLANT FOR 480,000 GALLONS PER 24 HOURS.
MATHER & PLATT, LTD., MANCHESTER

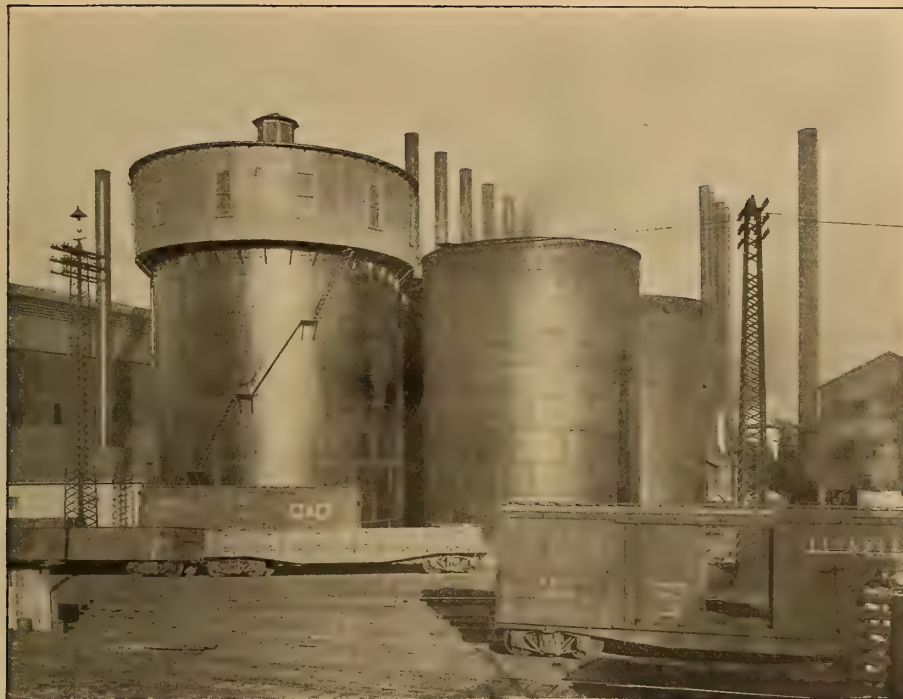
be used. It must be remembered, however, that they have only an approximate value. Quite as much depends upon the character of the salts producing hardness as upon their amount.

Hardness (Parts per million)	Classification
0 to 10	Very soft.
10 to 20	Soft.
25 to 50	Slightly hard.
50 to 100	Hard.
100 to 200	Very hard.
200 to 500	Excessively hard.
500 or more	Mineral water.

With respect to the character of the constituents hard waters may be classified as follows:—

1. Chlorated or muriatic waters.
2. Carbonated waters.
3. Sulphated waters.
4. Sulphuretted waters.
5. Ferruginous, or chalybeate waters.
6. Acid waters.
7. Alkali waters.

It would be interesting, if space permitted, to consider the chemistry of these waters and the relation between the different classes and the geological formations with which the waters have come in contact. The hardening constituents are, of course, derived from the earth. Rain water is in itself a good solvent, and by its absorption of carbonic acid, nitrates, etc., from the atmosphere increases its power of action on the rocks. Chlorine and other salts in rain water are blown in from the sea. Carbonates in water are due largely to the solvent action of the carbonic acid, which is derived in part from the air and in part from decaying organic matter. Nitrates are taken up by direct solution or by the oxidation of nitrogenous matter under the influence of bacterial life. Sulphates may be due to direct solution or to oxidation of iron pyrites. Many of



KENNICOTT WATER SOFTENER AT THE CARNEGIE STEEL CO., DUQUESNE, PA. CAPACITY, 150,000 GALLONS PER HOUR

these reactions here stated simply are in reality very complicated.

ANALYSIS OF HARD WATERS

The old method of determining the hardness of water was by the use of Clark's soap test. This method gives reliable results when the hardness is low, but involves many inaccuracies when the hardness is high. Though still much used, it is gradually being superseded by more exact methods of chemical analysis, which are too long to be included in the present paper. The best complete description of them is given in the report on Standard Methods of Water Analysis of the American Public Health Association.*

Complete mineral analyses by gravimetric methods are no longer considered necessary, and they are being gradually superseded by shorter

volumetric processes. Most of the analyses now made are in connection with water softening processes. It has been found that for the purpose of calculating the chemicals necessary to be used only the following items of the analysis are really necessary:—free carbonic acid, free acid (calculated as H_2SO_4), alkalinity, incrustants, and magnesium. From these determinations the other necessary constituents can be determined by calculation. For some purposes, however, complete mineral analyses are necessary.

The old method of expressing the results of hardness determinations was in degrees of hardness, or grains per gallon. The present standard method is in parts per million. As both of these methods are now used, and as, furthermore, different methods are used in Europe, the following factors for converting one to the other may be found convenient:—

* This report can be obtained from Dr. Edwin O. Jordan, University of Chicago, Chicago, Ill.

VALUE OF ONE DEGREE OF HARDNESS
IN PARTS PER MILLION BY WEIGHT

Standard American Practice.—Parts per million as calcium carbonate.....	1.0
America.—Grains per U. S. gallon as calcium carbonate	17.1
England.—Grains per imperial gallon as calcium carbonate	14.3
France.—Parts per 100,000 as calcium carbonate	10.0
Germany.—Parts per 100,000 as calcium oxide, ...	17.8

PRINCIPLES OF WATER SOFTENING

The chemical treatment of water dates back to antiquity. Certain chemicals were even used by the Chinese and Egyptians. Chemical treatment of water for the removal of hardening constituents began about the middle of the last century, with Clark's suggestion for using lime to remove lime and Porter's suggestion for using soda ash to remove the incrusting constituents. Nothing better than the use of these two chemicals has been suggested since that time, but the methods of using them have been vastly improved, both in the character of the apparatus used and in the method of operation.

The object of the application of lime is to neutralize the free and half-bound carbonic acid, precipitating calcium carbonate and magnesium hydrate. The object of the soda is to convert the sulphates, chlorides, etc., into carbonates, so that they may be precipitated by lime, as above mentioned.

The following figures show the quantity of chemicals required for the various constituents of hard water. For each part per million of the substances mentioned in the first column it is necessary to add as many pounds per million gallons of lime and soda as are given in the second and third columns.

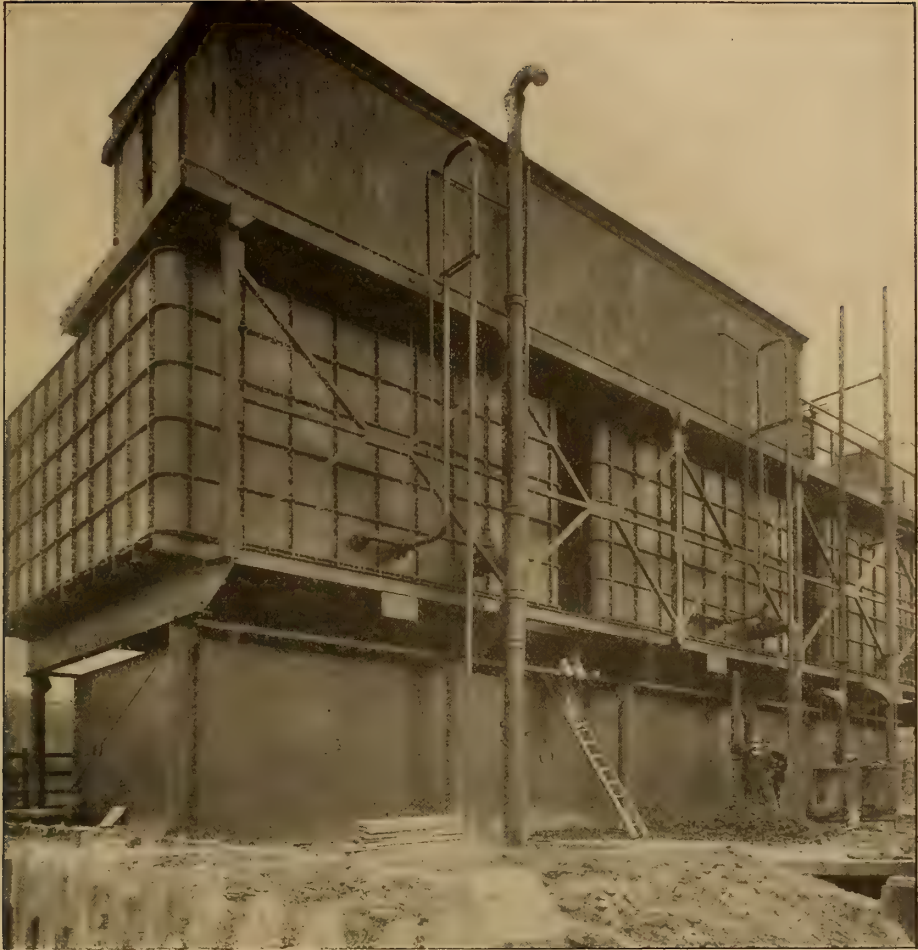
For Each Part Per Million of	Chemicals Required in Pounds Per Million Gallons	
	Lime	Soda
Free CO ₂	10.62	0
Free acid (calculated as H ₂ SO ₄)	4.77	9.03
Alkalinity	4.67	0
Incrustants	0.00	8.85
Magnesium	19.48	0

The above figures do not take into account any impurities in the chemicals. These have to be considered, however, in actual operation. If one knows the character of the water, it

is possible to calculate with close precision the amount of chemicals required. Often, however, the untreated water varies in quality to such an extent that it is necessary to make frequent changes in the amount of chemicals required. It is possible, by making continual analyses of the raw water, to observe these changes and vary the amount of chemicals accordingly, but in actual practice it is easier and better to study the character of the treated water and to determine from its analysis how the chemical feeds should be changed. By means of three simple tests this can be done. Determinations of the total hardness, alkalinity and causticity furnish the necessary data, and these may be obtained by simple tests which the engineer in charge can make. The ideally treated water should be one in which the causticity is about one-half the alkalinity, and in which the alkalinity and total hardness are the same. It is possible to reduce the hardness of almost any hard water to about 50 or 60 parts per million.

Waters to be used for different purposes require somewhat different chemical treatments. For example, a water to be used in a large stationary boiler may be treated with soda to the point of excess, thus taking advantage of all the removal of the hardening constituents possible, but in the case of locomotive waters an excess of soda would be likely to cause objectionable foaming. For some manufacturing purposes, and for general domestic uses, it is necessary to supply a certain amount of carbonic acid to the softened water in order to change the lime back to calcium bicarbonate and thus prevent troublesome deposits of lime on the pipes, meters, valves, etc. Little attention thus far has been given to this part of the process, but in large city plants it is one of the important elements.

The process of water softening, when coupled with mechanical filtration, may be made to yield a water



BOLSOVER DISTRICT WATER WORKS. WATER SOFTENING INSTALLATION FOR 360,000 GALLONS PER 24 HOURS. MATHER & PLATT, LTD., MANCHESTER

not only good for industrial uses, but safe for drinking purposes. If the magnesium content of the water is sufficient the use of alum, iron or other coagulants may be dispensed with, and the flocculent hydrate of magnesium may be depended upon to entangle the bacteria, clay, and fine suspended matter, so that after a rapid filtration through sand the water becomes clear and safe and wholesome.

PRACTICE OF WATER SOFTENING

Since the middle of the nineteenth century, when the first water soften-

ing plants of large size were built in England by Porter and Clark, the art of water softening has passed through a series of very interesting evolutionary changes. The original forms of apparatus were simple, crude and not always efficient. Although started in England, it was in France and Germany that the process received its first important developments, and it was by the French that improvements were made which foreshadowed the type of softener now so extensively coming into use in the United States.

Water softening plants have been constructed both on the intermittent



CRITON SOFTENER ARRANGED FOR TREATING JET CONDENSER WATER FOR BOILER FEEDING. PULSO-METER ENGINEERING CO., LTD., READING

and continuous plans. In the former a certain quantity of water receives its proper dose of chemicals and is allowed to stand in a tank until the resulting precipitate has settled. The dose is varied according to the quality of the raw water, and in the case of a water of variable quality

this method has its advantages. It requires, of course, a large tankage compared with the daily yield of the plant.

The plants which operate continuously, are more generally satisfactory. They require, of course, more complicated appliances for properly feed-

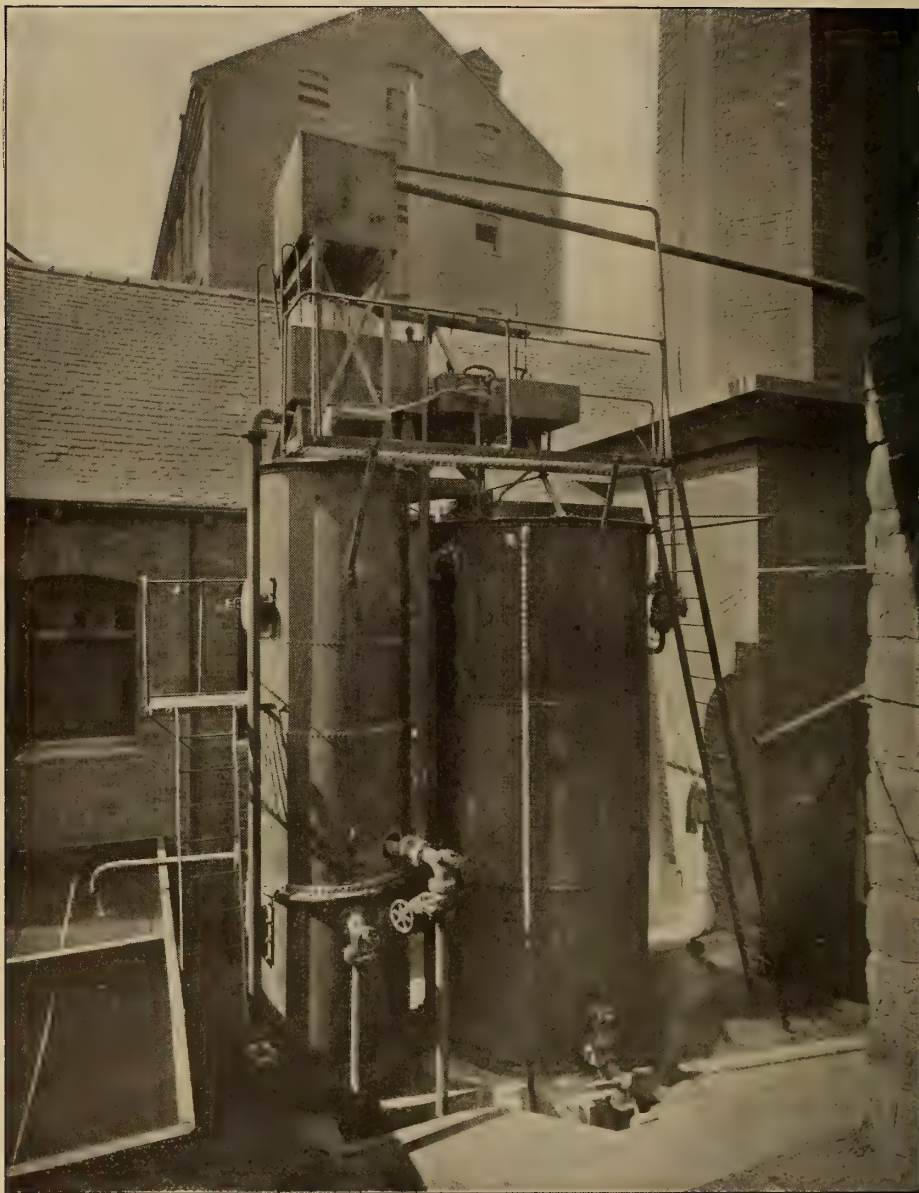
ing the chemicals, but all the inherent difficulties are being overcome; automatic regulating devices are being perfected, and the principles of the proper control of the chemicals by simple analyses are being better understood. The fact that plants operated by the continuous method require less ground space is often an important advantage; but, on the other hand, they demand more head room. Local conditions will often govern the type to be selected.

In the past the chief reliance has been placed on sedimentation to re-

move the lime and magnesia precipitated from the water, although a crude filtration through excelsior or sponge has been resorted to; filter presses have also been used. In the future, however, there is reason to believe that greater relative attention will be given to the filtration end of the process, especially in the case of supplies where the softened water is to be used for domestic as well as industrial purposes. The municipal water softening plant of the future will resemble a mechanical filter, but with a greater development of



ARCHBUTT-DEELEY WATER SOFTENING PLANT FOR 36,000 GALLONS PER 24 HOURS.
MATHER & PLATT, LTD., MANCHESTER



CRITON WATER SOFTENER AS INSTALLED FOR PURIFYING BOILER FEED WATER. PULSOMETER ENGINEERING CO., LTD., READING

the sedimentation basin and more elaborate devices for chemical treatment.

The cost of water softening plants depends upon the size of the installation. The smaller plants are relatively much more expensive than the larger plants. Thus, a plant of 5000 gallons per hour capacity might

cost \$5000, or \$1000 per 1000 gallons, while a 100,000 gallon plant might cost \$25,000, or \$250 per 1000 gallons, these figures referring to the common type of softener for industrial uses. The expense of operation varies naturally with the quality of the water, the amount of chemicals needed depending upon the hardness



WATER SOFTENER AND FILTER FOR DEEP MINE WATER. PATERSON ENGINEERING CO., LTD., LONDON

of the water. Chemical cost of from 2 cents to 5 cents per 1000 gallons are common.

As the hardness of water affects not only the manufacturer, but also every individual consumer, it is safe to predict that in the future the softening of water will be carried on in connection with public works

rather than at separate manufacturing plants. Large plants can soften water at less cost per million gallons than smaller plants, and in time manufacturers will come to learn that, all things considered, it will be better for them to pay their proportional part of a municipal water softening plant than to spend money for private in-

stallations. The idea of softening water for municipal use has gained considerable headway during the last few years, although at the present time there are only a few cities where it is carried on.

At Southampton, in England, the public water supply has been softened since 1888. The water is drawn from the chalk region, and is heavily charged with calcium carbonate. The sulphates are low, as well as the magnesium, consequently a simple treatment with lime is all that is necessary. This treatment reduces the hardness from 225 parts per million to 80 or less. The process consists of adding the lime, letting the water settle for about forty minutes in a settling basin, and filtering through a series of cloth filters placed vertically in small rectangular tanks. One of the interesting features of the plant is the method of cleaning the cloths. This is done by means of jet sprinklers, which move up and down between each pair of filter cloths and wash away the accumulations in two or three minutes. The filter cloths last about one year.

The largest municipal water softening plant in America is at Winnipeg, Manitoba. This was constructed in 1899. It has a capacity of about three million gallons per day. Lime is the only chemical used to reduce the hardness. The raw water contains about 200 parts per million of carbonate of lime and something over 100 parts per million of carbonate of magnesia; the hardness of the treated water has a residual alkalinity of about 80 parts per million. The raw water also contains about 175 parts per million of sulphate hardness, but no attempt is made to reduce this. An interesting feature about the plant is the process of re-carbonation, that is, the addition of carbonic acid to the treated water. This is done by passing the fumes of burning charcoal through the filtered water.

In Oberlin, Ohio, a municipal water

softening plant was established in 1903. It has a capacity of about 165,000 gallons per day. Lime and soda are the chemicals used. Settling takes place in reservoirs which have a capacity of about four days' supply. The water is filtered through a mechanical filter before being sent to the city. The carbonate hardness of the raw water is about 175 parts per million and the sulphate hardness about 150 parts per million. The alkalinity of the water is said to be reduced to about 30 parts per million by the process. From 6 to 17 grains per gallon of lime are used and from 2 to 6 grains per gallon of soda. The cost of the works is given as about \$12,000.

At Columbus, Ohio, where the water is excessively hard, a water softening plant with a capacity of 30 million gallons per day is being constructed at a cost of over half a million dollars. The principles of the process are the same as those described above, namely, treatment with lime and soda, settling and filtration. Among the interesting features of the plant are ingenious devices for thoroughly mixing the chemicals with the water, automatic appliances for regulating the flow, the use of long periods of settling, the use of raw water and sulphate of iron to remove caustic alkalinity, and the use of mechanical filters of large size.

Conservative estimates based on the use of soap in the household have shown that the value to the consumer of a hard public water supply may be increased by softening anywhere from \$10 to \$50 per million gallons, according to the character of the water treated. The saving in soap alone is often enough to pay for the cost of the process. When the economies to manufacturers are considered, and when, finally, it is seen that the process of softening may be made to give an efficient sanitary purification of the water, the advantages of municipal water softening plants become unmistakable.

REFRIGERATION ON SHIPBOARD

By Joseph H. Hart

THE problem of mechanical refrigeration in ship design and operation cannot be said to-day to be in an entirely satisfactory condition. Not only are the requirements in ship refrigeration to-day depending on the nature of the refrigeration required, but mechanical refrigeration is to-day undergoing developments which render the situation uncertain, and at this date mechanical refrigeration is more often than otherwise utilized in its application to the cooling of ships in a hit-or-miss manner, which to the ordinary refrigerating engineer is a matter of extreme regret, and would be equally so to the naval engineer if he were at all familiar with existing conditions and the situation from a refrigeration point of view.

In the first place, the fact that refrigerating conditions are different, depending upon the nature of the refrigeration required and the general plan and purpose of the ship, is generally a matter of small concern to the refrigerating machine manufacturer, and the naval designer, in his turn, has not sufficient knowledge of mechanical refrigeration to insist on a suitable installation.

Mechanical refrigeration has only within the last few years become general in naval architecture, and the requirements for different shipping conditions are becoming more and more pronounced. Further, mechanical refrigeration is steadily undergoing changes in its development, and the relations of the two are, to say the least, in an extremely chaotic state. As an illustration, there are several types of existing refrigerating machines at present in practical operation. All of these machines claim special advantages in marine installa-

tion over other competitors, whereas the fact of the matter is the special advantage of each depends primarily on the purpose it serves in marine construction, and generally the installation, in nearly every case, is absolutely independent of the requirements from the best engineering point of view.

Refrigeration as applied in marine operation can be divided generally into two great classes. First, the class where mechanical refrigeration is of the greatest importance in the maintenance of the ship as a useful factor in the transportation of refrigerated products. The second case involves the installation generally of a small refrigerating plant for the purpose of preserving provisions for more or less extended periods of time, and as a convenience rather than a necessity in the maintenance of best conditions on shipboard.

Now these two purposes are entirely different, and require different installations from a refrigerating point of view. Thus, where the refrigerating machine serves the second purpose, many of the inconveniences and dangers incident to a number of refrigerating machines are unnecessary and undesirable. Often the efficiency of operation and cost is a minor factor in comparison to convenience and compactness. This is often the case in steamers constructed for passenger trade on the ocean and Great Lakes. On the other hand, where refrigeration is used to cool an entire cargo, efficiency becomes a matter of prime importance, largely on account of quantity of refrigeration required. The other factors do not possess the same relative importance, and hence the factors determining the style of the machine for

any particular purpose vary in weight in accordance with the purpose for which the installation is required.

Now, in order to see all this more clearly, it is necessary to review briefly the various types and methods of refrigerating machines on the market, stating the special conditions or advantages and disadvantages inherent in their application in this field, together with their relative efficiencies under conditions apt to obtain. Thus, we have to-day refrigerating machines which use air as the cooling agent, others utilizing liquid ammonia, and still others utilizing liquid carbon-dioxide gas. The various advantages of these types are generally recognized in ordinary mechanical installations, but in the naval development each has set forth peculiar claims for superiority which are more or less debated and contested by each, and the situation is not clear. Thus, under ordinary refrigerating conditions, it is generally recognized that ammonia is much superior to all other substances as the means of conveyance of the heat from the refrigerating chamber, and it occupies a position in this field analogous to that of water in power production. Further, mechanical refrigeration with air by means of balanced expansion is to-day regarded as inefficient, and the first-cost factor is three or four times as great, in comparison to ammonia, with machines of equal refrigerating capacity. Carbonic acid, or carbonic anhydride, as it is sometimes called, is also generally regarded as considerably less efficient than ammonia, although the issue at this point is not so pronounced. In order to understand this development further and see clearly the varying conditions which determine the efficiency of these machines on ship board, a brief review of their actual operation and influencing conditions will be necessary and they will be taken up in the order named.

Air machines which utilize balanced expansion produce refrigera-

tion by making the air do work. It is collected under pressure by a pump and then allowed to drive an engine which takes the heat from the air in precisely the manner that a steam engine takes the heat from the steam. Air can be cooled by this method to 140 degrees below zero. The apparatus is clumsy, however, and is costly in installation and maintenance. This process is developed in two machines to-day,—the Bell-Coleman and the Allen dense air machine. In the Bell-Coleman type, air is drawn from the atmosphere, compressed, and then cooled off in condensing coils by running water. It is then allowed to do work in the expanding cylinder and into the refrigerating chamber, or the refrigerating coils, at the atmospheric pressure. The air is constantly renewed and this process combines ventilation as well with its operation. The Allen dense air machine is similar to the above, but it has further a small pump which supplies a closed system with air at a fixed pressure. This air is compressed in the compressor and then cooled off in the same way, and then allowed to expand in the expansion engine to the pressure existing in the system. It thus goes through a closed cycle, the same air being used over and over again, barring leakage. This process is more efficient than the previous one, since it operates at higher pressures and uses the same air over and over. Further, it is in general more compact in construction on this account and this is a condition which must be necessarily considered in ship installation.

The ammonia machine utilizes the evaporation of liquid ammonia to produce refrigeration. It does this by a process analogous to the absorption of heat by water in a steam boiler. Any volatile liquid could be used, but ammonia possesses the highest latent heat of evaporation of any known substance, next to that of water, and its boiling point, under normal pressure conditions, is much

below that of water. A cask of liquid ammonia would boil away and produce refrigeration in precisely the same way that a refrigeration machine does if it were allowed to stand. However, the ammonia would have to be replaced, and this is the sole reason for the machinery in modern refrigerating plants. The reproduction of the liquid ammonia in mechanical refrigeration is accomplished in two ways. In the compression system the vapor from the liquid ammonia is compressed in a compressor and liquefied under these conditions by cold water in the condensing coils. In the absorption machine the same process is accomplished by the use of aqua ammonia, or a mixture of ammonia and water. Water possesses the peculiar property of absorbing large quantities of ammonia gas when cold, and the loss of this property with rise in temperature. In the refrigerating process by this development, ammonia gas is compressed by heat in a boiler, or generator, in precisely the way steam pressure is generated in a boiler. This is condensed in the condensing coils by means of cold water, and when the liquid ammonia evaporates the gas generated is absorbed by cold water which is then forced into the ammonia boiler, or generator again and the cycle is made a closed one.

Now, these two processes are close competitors from an efficiency point of view and outdistance all other types. The efficiency of each of these machines is dependent upon its conditions of operation. The refrigerating capacity in both cases depends simply upon the amount of ammonia condensed and re-evaporated. Thus, in the compression system the capacity depends simply upon the size of the compressor and its capacity for ammonia gas. The boiling point of liquid ammonia depends upon the pressure above it. Under ordinary rated conditions this is assumed to be a pressure of 15 pounds to the square inch, and this means that the ammonia will not pro-

duce a much lower temperature than 16 degrees F. Diminution in temperature required in refrigeration means, in this case, a diminution in capacity, since the suction pressure on the compressor must be diminished, and this results in a loss in ammonia capacity per stroke of the piston. An absorption machine, however, works, if anything, more efficiently with a low temperature of the ammonia. Thus, a compression machine has its best efficiency for mild refrigeration, an absorption its best for extreme refrigeration. Further, a compression machine utilizes live steam to drive the compressor, an absorption may utilize exhaust steam traversing pipes through the generator. The capacities are such, from a steam consumption point of view, that an absorption machine of equal capacity can be operated from the exhaust steam alone of a corresponding compression plant. This is well within the limits of accuracy and some authorities consider its capacity under these conditions as twice that of the compression plant. Further, an absorption machine derives no benefit from the utilization of high pressure or superheated steam. The quantity of heat in the steam is approximately the same under these conditions since the latent heat of change of state diminishes with rise in temperature and pressure. Thus, the absorption machine often obtains its best efficiency as operating in conjunction with a compression plant, utilizing the exhaust steam from this to operate its own generator, whereas, an ordinary compression plant is generally on an eight to one basis; that is, eight tons of ice produced to one ton of coal consumed; an absorption machine of the same capacity easily operates on a eleven to one basis and a double machine of the same indicated capacity,—half of the compression system and half of the absorption system,—can easily operate on a fourteen to one basis. Now, we come to the disadvantages of the absorption machine. Its first cost is

higher for small units. It requires a larger number of distinct units in its operation and these generally occupy more space, and their accumulative cost is greater. Above 20 tons refrigerating capacity, however, these two types approximate the same in regard to the first-cost factor, since at this point compression machines must necessarily utilize compound condensing engines of high first cost and high efficiency. Above this capacity absorption machines rapidly diminish in first cost in comparison with the compression type and do this in almost direct ratio to their size.

Carbonic anhydride machines are analogous in operation to ammonia compression machines, but use carbonic acid gas as the refrigerating substance. This material, while possessing a much less latent heat of evaporation, has a much greater specific gravity, and, further, utilizes much higher pressures in the compressor, thus increasing the efficiency of the production. A compressor for this material occupies considerably less space than a corresponding ammonia compressor on this account. The pressure attained in this type is in many cases objectionable, as 900 to 1200 pounds is the condensing pressure of this type of machine, whereas ammonia machines seldom rise over 180 pounds. The particular advantage, however, of the carbonic anhydride type is the nature of the substance itself. It is not injurious and since leaks in any system are almost inevitable, ammonia is often very objectionable in confined places, as are the rule in ship design, and hence this is no mean factor. The Northern Steamship Company boats, on the Great Lakes, have installed this system, which has proved satisfactory in their particular field.

This brings us now to a consideration of existing marine conditions for freighters with large cargo capacity and utilizing a large amount of refrigeration. The ammonia machine

is the only available type for yachts and passenger boats, the air machine and the carbonic anhydride system divide the field with the ammonia machine. The efficiency of the latter is so great in comparison to the other and its first cost so much less that it is a matter of choice and expenditure in this development. An ammonia machine can be made thoroughly satisfactory under these conditions and hence the problem becomes largely a matter of choice.

Now, in large refrigerating units, ammonia, as has been said, is much superior in every way. Of the two systems the choice of installation depends on a number of factors. Extreme refrigeration is not a pronounced factor in this work as it is in some developments on dry land. The object of the refrigeration is generally the storage of perishable products and thus need not require a very low temperature. The temperature required, of course, depends on the nature of the product. In the fruit trade a much higher temperature can be allowed than in meat transportation. For the first the compression machine probably has a large advantage on account of increased capacity of compressors above rated capacity owing to the high suction pressure permissible under these circumstances. Further, in the tropics, often exhaust steam is not sufficiently hot to produce the requisite ammonia pressure in the generator and condensing coils for condensation with the high temperature condensing water at hand, hence the pressure must be increased and this means a loss in efficiency of the units from which the exhaust steam is derived. Further, the absorption machine occupies considerably more space as a whole, but it is in a large number of comparatively small units, and thus can be stowed away in odd corners of the boat at any distance apart; hence this is not as large a factor as is generally considered. It can be said briefly that in this choice of refrigerating system local conditions

hold almost entirely. That they may be accumulative and amount to a large factor in the operation of the plant and in the profits obtainable is a foregone conclusion. Thus, every refrigerating machine installation in naval work should have the assistance of a competent refrigerating engineer, or at least marine engineers should become much more familiar with mechanical refrigeration.

This does not represent the entire situation by any means. The utilization of ammonia in either the absorption or the compression type is but the first step in the installation. The refrigeration by ammonia is produced to-day in three ways, any one of which may be most efficient under different conditions, and this situation must also be faced by the naval contractor. Thus, ammonia machines are cooled by direct expansion or by brine cooling or by air cooling. This latter has no connection with the direct air cooler mentioned previously. In direct expansion the liquid ammonia is allowed to run into the cooling coils and evaporate there, producing the refrigeration in the pipes, which, in turn, absorb the heat from surrounding objects. Now, these pipes are often long and have many fittings and must be able to withstand the ammonia pressure if at any time the machine ceases operation, and there must be no leakage. These conditions are such that the installation of direct expansion is often costly and always liable to break down from deterioration and faulty construction. The indirect or brine system was devised to eliminate some of these conditions. The ammonia liquid is evaporated in a device known as the shell cooler and it here cools brine, which is in turn made to circulate through the refrigerating coils. These coils need not possess the strength or durability of direct expansion coils and the saving is great, although the refrigeration is often more inefficient on account of the losses involved. However, this system enables one to possess a safe-

guard against possible breakdowns or stoppages for short periods. The direct expansion machine is such that when stopped the system would rapidly become warm by radiation. A large brine tank, however, can be used and the brine then pumped through the refrigerating pipes even after the refrigerating machine itself has stopped, and thus it is a factor of safety in preventing the destruction of perishable products through unavoidable stoppages of the refrigeration machinery. In air cooling, the air is cooled by direct expansion and is then, in turn, forced by blowers or pumps into the refrigerating department. This latter is often common where the refrigeration need not be extreme and its ventilation is one of the necessary conditions. However, both direct expansion and air expansion do not possess the storage battery factor that the brine system does. This is a factor that too much stress cannot be laid upon, and often where the air machine is used the brine system should be installed, the brine cooling the air instead of the direct expansion pipes cooling it.

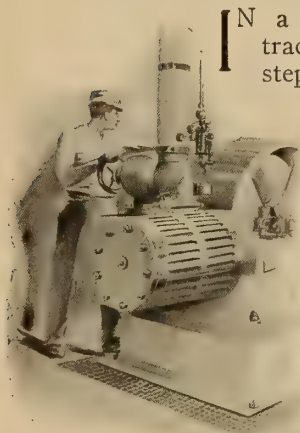
In general the marine engineer knows comparatively little about the requirements of mechanical refrigeration. Spaces are utilized in the ship for this purpose which are often not only undesirable from a refrigerating point of view, but many times absolutely impracticable for the operation of the plant. Further, the possibilities of utilizing various units of refrigerating machinery is a matter for expert investigation as there is often much saving by means of the utilization of gravity in the flow through pipes, and a number of other conditions enter, especially the situation of the condensers. All this work should be in the hands of a refrigerating engineer in conjunction with that of a marine expert and should not be given in a lump to contractors for installation, when these men are often as lacking in knowledge of the conditions as the marine expert himself.

CONSTRUCTION INSPECTION OF BOILERS AND ENGINES

II.—INSPECTION OF ENGINES DURING CONSTRUCTION

By J. R. Thompson

In the February issue of this magazine there was given a discussion of the manner in which a conscientious and tactful inspector goes about his work when following the construction of a steam boiler, and in the course of that article a number of modern processes involved in boiler making were reviewed. Mr. Thompson now proceeds to the second phase of the subject of inspection, dealing with the building of steam engines which, on account of the importance or nature of the conditions, demand the attention of an inspector representing the purchasers. A following paper, concluding the series, will deal with the testing of boilers and engines, and the relation of the representative of the purchasers with this element in the execution of a contract.—The Editor.



In a previous article we traced the successive steps in the progress of a thorough-going examination of a Lancashire boiler under construction. Merely as an example of boiler building, the type selected for illustration was amply sufficient to demonstrate the methods which should be pursued in order

that no detail, however unimportant, may escape detection.

But, after all, the inspection of a boiler in its manufacture is a straightforward business by comparison with the correspondingly minute examination of the thousand and one separate parts which go to the formation of a modern steam engine.

For example, the boiler, though built up of a considerable number of pieces, is practically repetition work right through. The thousands of rivets which unite its component parts into one homogeneous structure have no individuality, and the plates themselves are but little more distinguished.

Far otherwise is it with the complex assemblage of fixed and moving

parts with which we shall now concern ourselves.

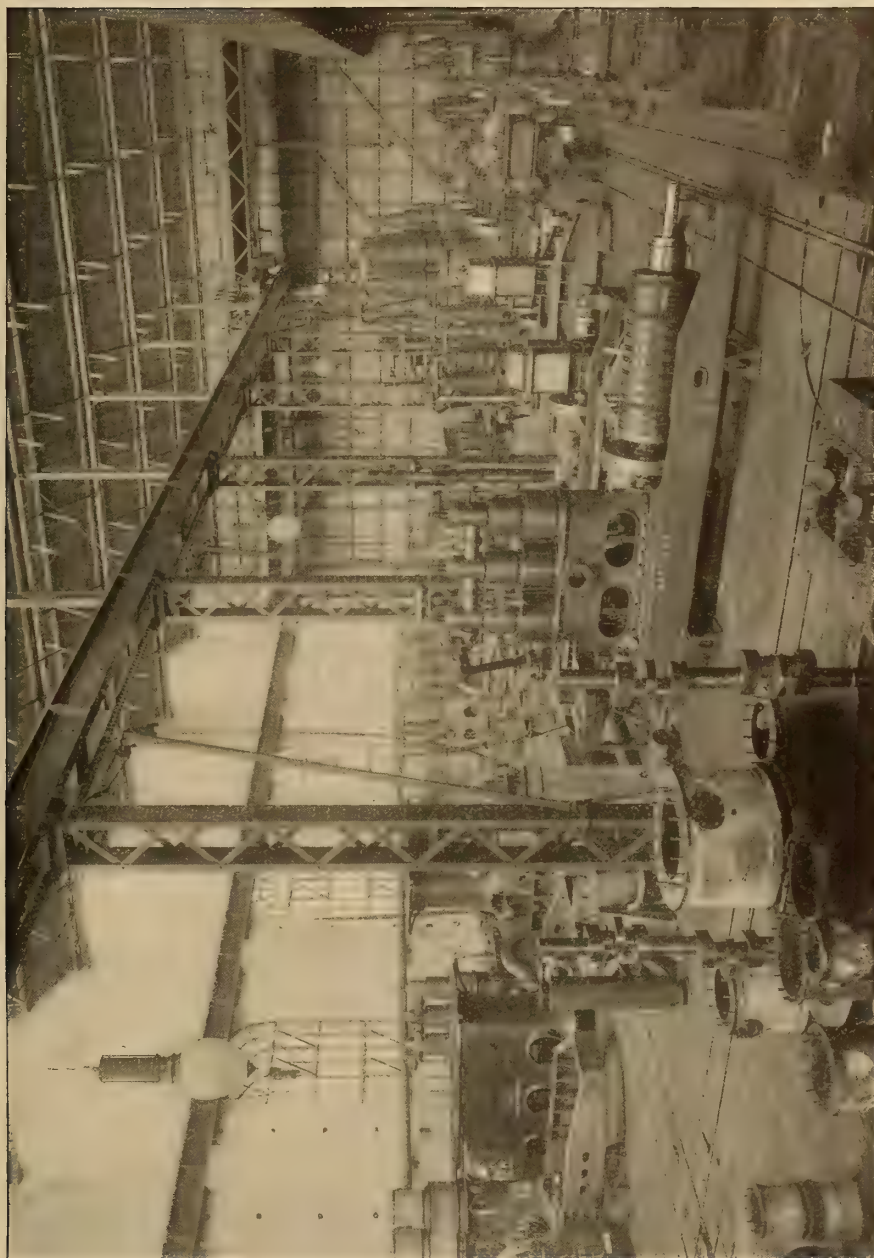
Every detail, large or small, has at some period or other been the subject of separate care and thought, and the resultant whole embodies the research of some of our finest intellects and the accumulated experience of a century's practice.

A firm or company desirous of replacing or extending their present steam plant may proceed in any one of several ways.

They may themselves have at command such technical skill as will enable them to fix upon, and issue specifications for, the complete drawings for the engines they conceive to be the most suitable for their purpose, if expense is no object.

They may employ to the same end a consulting engineer or one of the several boiler insurance companies, or finally they may simply state their requirements, and invite tenders direct from several firms of engine builders, leaving the exact form and dimensions to be determined by the makers in competition, awarding the contract to the firm whose offer as regards price and guaranteed steam consumption appears to be the most favourable under the given conditions.

We are, of course, assuming that the size of the steam plant under consideration, the cost per ton of the proposed fuel, and the accessibility



A BRITISH ENGINE WORKS. THE ERECTING SHOP OF WILLANS & ROBINSON, LTD., RUGBY

of the site are such as to demand a high-class job.

Engines and boilers of small size are bought and sold with little ceremony, and again it would be a waste of money to put down, even for large powers, highly economical compound or triple-expansion engines where the fuel available was valueless and of negligible cost, as in the case of a sawmill or timber converting factory.

There are numberless factories to be taken into account in settling the design to be adopted, but it may be taken for granted that, unless the conditions are absolutely novel (which is highly unlikely, some one or other of the regular standardized designs submitted by the competing engine builders will be found to meet the case, and will be better value for money than any specially constructed plant is ever likely to be.

There are, of course, exceptions to every rule, but in matters of this kind they are few and far between.

The approved drawings and the full specification, however they may have been obtained, are now, we will suppose, in the hands of the inspector,—the person appointed to supervise the construction, in the sense of being responsible that the contract is fulfilled to the letter.

It will be his duty during construction to examine the material and the workmanship, and afterwards to test the efficiency of the completed engines.

Armed with the necessary authorization, he will doubtless find it necessary to pay a preliminary visit to the contractor's works, for the purpose of making himself familiar with the procedure adopted in that establishment.

He will take the opportunity of going over any points in the specification which may not be clear from the drawings he is furnished with, and will ascertain approximately the dates upon which an instalment of the principal castings or forgings will be ready for his inspection.

Some weeks later on he will re-

ceive an advice that, say, the cylinder bodies, the liners, one or both of the bed plates, and the main shaft, are in the rough and ready for inspection.

Concurrently with these there will probably be a considerable quantity of the smaller castings and forgings.

Examination at this stage is frequently omitted, as beyond the assurance that the parts in question are actually in existence at the date named and are apparently sound, little can be done beyond the verification of the test pieces.

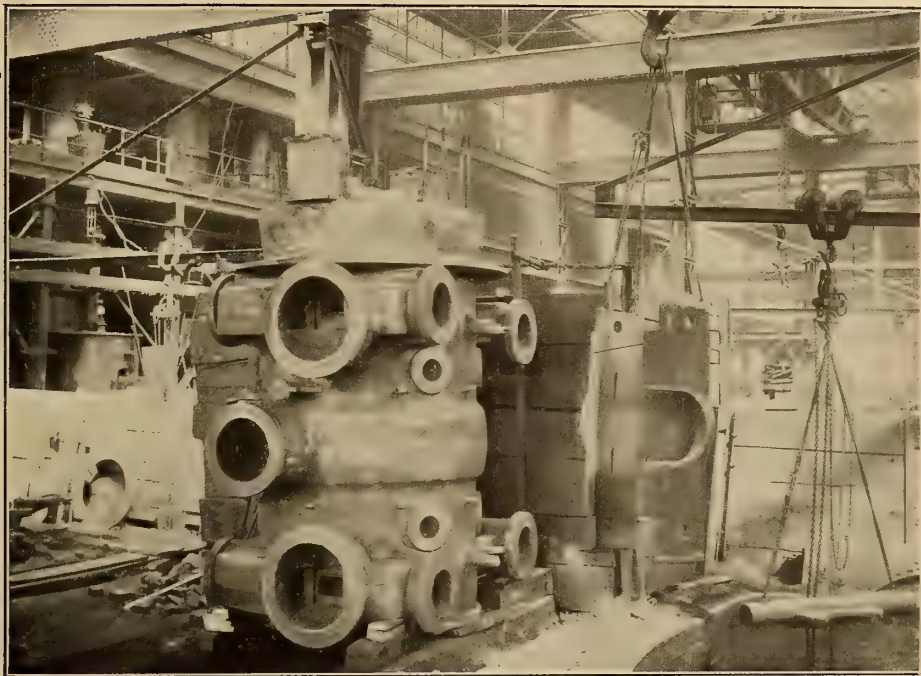
These, in the case of castings, are small bars, usually 12 inches long by 1 inch square, which are moulded alongside the more important castings and cast in one piece with them, being then carefully broken off and preserved.

Sample pieces are also taken from the main shaft, connecting rods, piston rods and crankpins, generally formed by leaving each of those articles a few inches longer than necessary, and drawing down the portions so cut off under the hammer to form convenient test bars for tensile and bending tests.

It is hardly conceivable that any firm of repute would knowingly produce false test pieces, hence, as already mentioned, the formal verification of the test bars by a comparison of their fractures with those of the castings off which they have professedly been broken is frequently omitted, and the bars are sent direct from the contractor, duly marked, to the testing establishment named by the purchaser. Here they are broken under the specified conditions, and a certificate is forwarded to the sender, simply stating that so many pieces marked in such a manner have been tested with results as enumerated.

This method, at any rate, has the advantage of being impartial and authoritative.

Assuming the results to be favourable, the contractor is enabled to proceed with a considerable amount of turning, boring and general machin-



A CONTINENTAL ENGINE FOUNDRY. ESCHER, WYSS & CO., ZURICH

ing, and to arrange a date for an inspection of certain parts under the hydraulic test.

The material of the bearings, gun metal, phosphor-bronze, or one of the various white metal compounds,—the latter presumably for the main bearings,—should now receive attention.

Samples of each of these, with the formula from which they are compounded, should be asked for, and if the specification be a stringent one an analysis may be asked for, but usually if the composition put forward is satisfactory on the face of it, this is dispensed with.

And, generally speaking, the inspector should never forget that his presence and action are in no wise intended to suggest any distrust of the contractor or his methods.

Whilst he himself has his duty to perform in the shape of seeing that the work done is up to the specification, yet an undue insistence upon matters of trifling importance, a too rigid adherence to his own personal opinion in cases of doubt, and a gen-

eral fussiness of demeanor, are sure signs of inexperience.

He is not a detective, but a preventive officer, and his important office loses in dignity and gains nothing in efficiency by prying and interference.

Foremen and workmen are quick to resent any liberties taken in their own ground, and a couple of instances where a well-deserved rebuke was administered to over-zealous inspectors (not the writer, be it understood) may be given here.

In neither case was any complaint or reprisal practicable, for reasons which will be obvious.

The "fussy" official had only himself to thank, and found it better to say nothing about the matter.

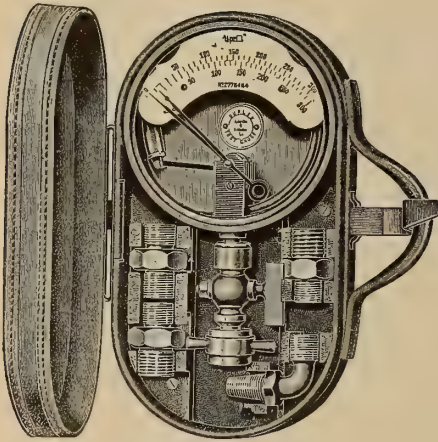
An inspector, not a bad fellow in himself, but noted for a habit of asking unnecessary questions and meddling with what did not concern him, was known to be on the premises, and was expected in a certain department. Shortly before his arrival a small block of bright steel

was carefully heated, until it assumed a bluish-grey colour, and deposited on a bench nearby. A conspicuous label,—a bit of sheet iron with the words chalked:—

"PLATINUM, DO NOT TOUCH," was put alongside, and all hands waited the result.

Sure enough, in less than five minutes the bait took, and the "Platinum" proved even heavier than the genuine article.

Such practices are, however, to be strongly condemned, and in this instance the man responsible got his discharge as a reward for his misplaced ingenuity.



INSPECTOR'S DUPLEX TEST GAUGE. SCHAEFFER & BUDENBERG, MANCHESTER

Scarcely less reprehensible was the following trick, which was played upon an inspector whose leading characteristic was a somewhat excessive self-confidence.

A most irritating man he was, with a manner, whenever he was engaged in his official duties, which said as plainly as words could speak:—"Now, my good man, it is no use attempting to take *me* in, so don't try any little games on *me*."

He was in the service of a foreign government and had some sort of decoration,—a fact of which he seemed sufficiently aware. It chanced one day that this man had a Corliss cylinder jacket to test, and the

fitter in charge made up his mind that, in his turn, he would test the inspector.

Upon the side of this cylinder body was cast a large hollow facing intended to carry the pin or pivot upon which the wrist plate oscillates, and in the centre of this facing was a core hole communicating with the jacket space and closed by a screw plug.

The fitter having, for his own satisfaction, duly tested the jacket, withdrew the screw plug from the core hole, and plugged instead the orifice of the flexible tube connecting with the portable force pump.

In due time the great man appeared, the fitter laboriously plied the hand pump until its pressure gauge having reached the specified figure, the inspector ordered him to stop, and, after a cursory look around, entered the particulars of the test in his note-book, stamped the casting with his official mark, and departed. Needless to say, he was not advised of the fact that there was not a drop of water nor an ounce of pressure in the jacket during his examination. The story, however, leaked out, though the water did not.

In large engines there is a good deal of hydraulic testing to be done, as, in addition to the jacket space (which tests the strength and soundness of both the cylinder body and the liner), every part subject to internal steam pressure must not only be of adequate thickness to withstand the stress assigned to it, but must demonstrate it by successfully resisting the hydrostatic (misnamed hydraulic) test of at least 50 per cent. in excess of the actual working steam pressure.

It is a great saving of the inspector's time, and involves no additional work to the contractor, if a number of pipes, bends or valve bodies having flanges of similar size are temporarily bolted together and put under pressure simultaneously.

Frequently it happens that owing to the misplacement of a core, one

side of a bend or pipe is thinner than it should be, though still strong enough to carry the test pressure.

This is not difficult to detect by a judicious application of an ordinary fitter's hammer, which by its degree of rebound, ranging from "lively" to "dead," will give a fair idea of the comparative thickness of a pipe or bend filled with water under pressure, while in very thin places the tapping of the hammer will start a crack.

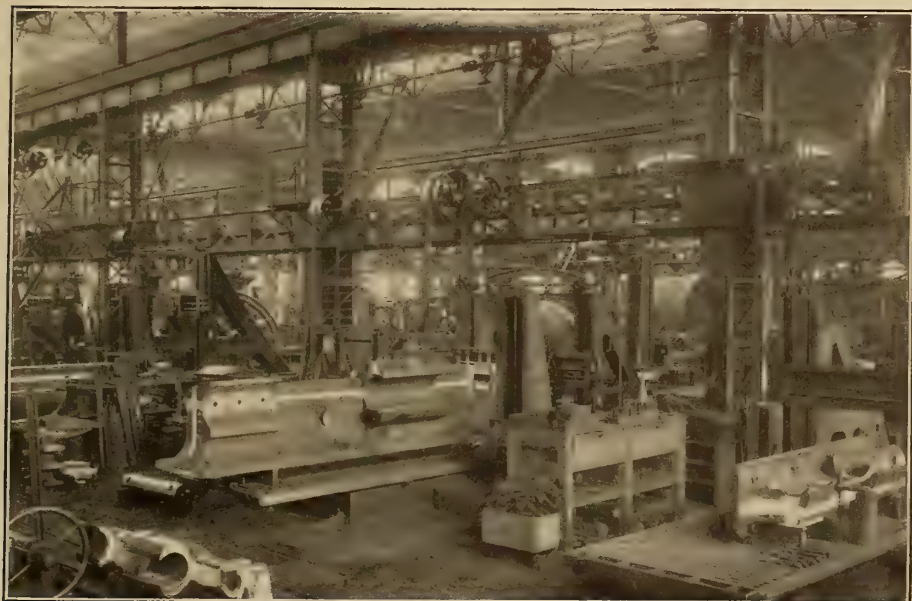
In particular the cylinder body should be examined in this way, and on suspicion of a thin place the inspector may desire that a small hole be drilled through at the presumed site of a defective area, through which an actual measurement may be made.

By the use of pipe calipers the thickness at any part of a hollow casting open at the ends may be directly gauged, and it is always open to the contractor in any case of difference of opinion as to thickness to demonstrate the correctness or otherwise of the inspector's assertion.

There are, of course, cases in which a slight deviation from the specified

thickness in a cast-iron pipe or bend is of little or no consequence, and indeed slight inequalities of this kind are actually provided for in determining the thickness of metal to be specified; but, on the other hand, the inspector has his duty to do, and the potential cost of replacing a doubtful casting, though it may be an important factor in the question from the contractor's point of view, should not be allowed to influence the decision of the man who is there to represent the purchaser.

Let us, for a moment, review the position of the inspector confronted with a "hard case." Here is an expensive casting, an engine frame weighing many tons, or a cylinder upon which a good deal of work has been done, and a defect is revealed which (the contractor's foreman is prepared to stake his existence upon it) is of no actual detriment to the engine as a whole. The inspector knows also that in all probability the engine would work out its allotted span, and thence, through the fire of the melting furnace, pass to a new incarnation and no one be the wiser. On the other hand, the replacing of



A CONTINENTAL STEAM-ENGINE WORKS. MACHINE SHOP AT MESSRS. ESCHER, WYSS & CO., ZURICH



A SET OF STANDARD INTERNAL AND EXTERNAL GAUGES. SIR W. G. ARMSTRONG WHITWORTH & CO., LTD., MANCHESTER

the defective part for the sake of a possibility will involve not only a considerable loss to the contractor, but probably some delay in completion.

His decision is eagerly looked for, and if he be of a sympathetic nature, he will be considerably exercised as to which course he should take. If the risk were his own solely, he might be inclined to give the benefit of the doubt and pass the defect.

This dilemma puts the case in a nutshell, and shows the value of qualified professional inspection. The purchaser, or the responsible user, inspecting in person, might be acted upon by sympathetic considerations, and might decide to take the risk, possibly to his own lasting regret later on. The professional inspector, on the other hand, has no choice in the matter, if he really believes there is any measurable risk incurred, and his clear course is to refuse to pass the defective article. The more important and expensive it is, the more disastrous would be any failure in the time to come. No; if the inspector would sleep 'o' nights he must not have possible consequences hanging over him of this kind. He is the trusted agent of the purchaser, and

nothing must induce him to lose sight of that fact.

Of vital importance, though not a subject for the hydrostatic test, is the bed or frame of the engine. This important casting, through which all the calculated stresses of the piston's reciprocation, tensile and compressive, are duly conveyed from the cylinder to the crankshaft, must carry throughout its length an unbroken minimum section of metal far in excess of theoretical requirements.

For now and then, once or twice only, perhaps, in the life of the engine, it will be called upon to withstand a water test in tensile strength strain which will tax its strength to the uttermost and before which something will have to give way,—the presence of entrapped water between the piston and cylinder end.

A flaw, therefore, in the metal of the bed, or an unsuspected thin place in the section, may, at the time of crucial trial, transform the situation from a matter of a sheared cutter or a broken piston-plate into a general break up of the engine.

However, we have devoted more than enough time to the consideration of the castings.

While we have been doing this a

considerable proportion of small finished work, connecting rods, valve gear, and the like, has been got ready for examination.

Beyond a general comprehensive looking over these detail parts the inspector will not, as a rule, trouble himself much as to their exact lengths, diameters and dimensions. It is much more to the purpose to see them after they have been erected on the engine, when any discrepancy or bad fitting becomes at once evident.

If the piston rods are coned to receive the piston-bodies it is important that the taper in the rod fits the conical hole in the piston accurately. One or more chalk marks drawn down the cone should be completely rubbed out when the rod is rotated in the conical hole, and the same applies to the fit of the other end of the rod in the cross-head, though in a lesser degree, as any wear of the taper can be followed up by the cutter.

The piston is usually tightened on the cone by a large nut, and the means of securing this should be carefully looked to.

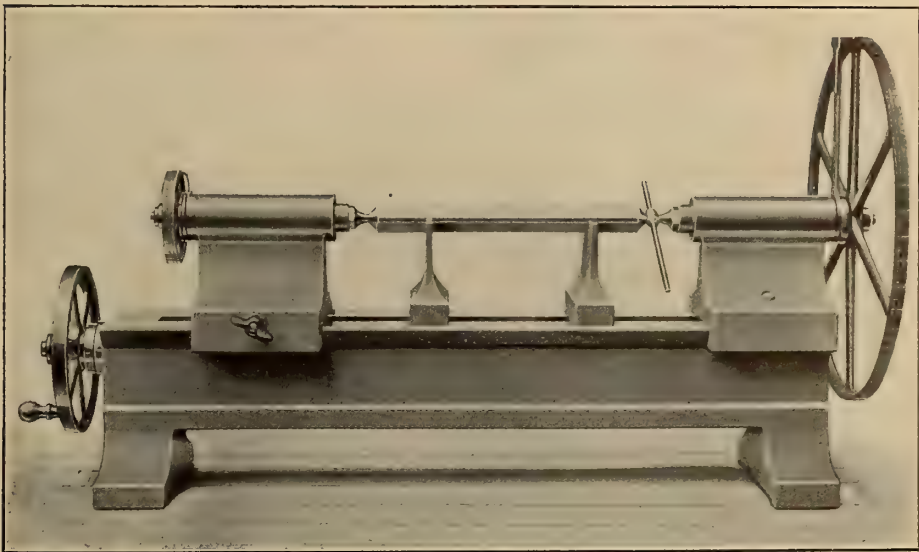
The amount of latitude which an inspector can allow himself in dealing with any particular works is very quickly determined the very first time that he comes into the place.

There are some, but very few, concerns accustomed to doing large engine work who, whether by slack supervision or from other causes, are constantly putting the inspector into an awkward position by submitting something to him which is not quite as it should be, and "trusting he will have no objection to pass it."

Or, worse still, they leave him to find out such cases for himself.

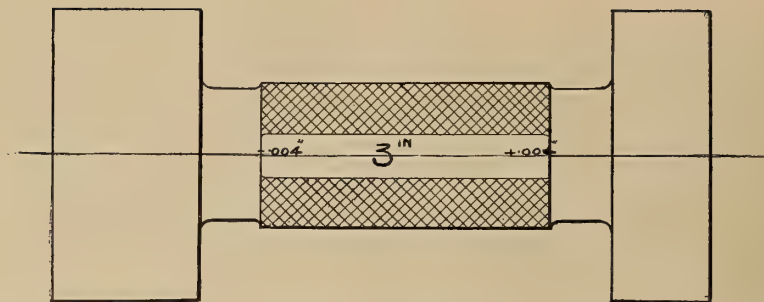
There are others, and generally more modern concerns, where it seems practically impossible for any imperfect workmanship to get through. Between the two extremes there are numberless gradations, and the inspector must make up his mind to look at every single thing in the one case, while in the other he may feel that his presence is almost unnecessary.

The main shaft, turned all over, lies on the shop floor. The crank discs or crank arms, as the case may be, are also finished and ready for



WHITWORTH MEASURING MACHINE

Arranged to measure by comparison with standard cylindrical length or other gauges up to 6 in. diameter and 12 in. long, and to the 10,000th part of an inch, or with vernier to the 100,000th part of an inch over small ranges.



INTERNAL LIMIT GAUGE, ONE-HALF SIZE. SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD. MANCHESTER

forcing or shrinking on. It is not any part of the inspector's duty to advise the contractors what allowance they should make for a shrinking or a forcing fit. If the specification does not determine which of these methods is to be adopted, he will be guided by the usual practice of the establishment.

All that he is responsible for is that the cranks or discs shall be properly fixed on the shaft, and the same applies to the crankpins.

Here, again, the hammer test comes in. Crank and shaft and pin should respond to smart strokes of a hand hammer by a clear, ringing sound, not to be mistaken by anyone who has once heard it.

In a shop where limit gauges are used the inspector may request that all parts of the engine which are in contact with wearing surfaces, as crank-necks, crank-pins, crosshead-pins, wrist-pins, rocking shafts, and the like, shall be calipered by their respective gauges.

The principle of the limit gauges, for there are a pair of them for every size, differing by a prescribed amount,—so many thousandths of an inch, according to size,—is that by the successive application of the two the one marked "Go on" shall be felt as it spans the object to be measured, while the second one, marked "Not go on," shall refuse to pass over.

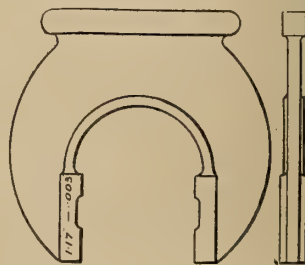
There is no springing of calipers or room for doubt in any way whatever. The dead square faces of the hardened steel plugs, screwed into rigid horse-shoe castings, form a

witness whose testimony cannot be disputed. If the first gauge will not pass over the shaft, the shaft or pin is too large; if the second gauge will, it is too small.

Between the upper and lower limits the difference may be as small as the nature of the work demands; for example, it would be absurd to apply the limit system to, say, the diameter of the connecting rod at the centre, where a sixteenth of an inch more or less makes no appreciable difference. But where accuracy is necessary that the dimensions are within an error of which the limits are absolutely known, is a modern refinement of which the value is becoming increasingly apparent.

It is true that absolute interchangeability, in the sense usually associated with the manufacture of small arms and sewing machines, is neither necessary nor desirable in the construction of a large steam engine.

From the mere conditions of temperature, take, as an example, the



EXTERNAL LIMIT GAUGE, ONE-HALF SIZE. SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD., MANCHESTER

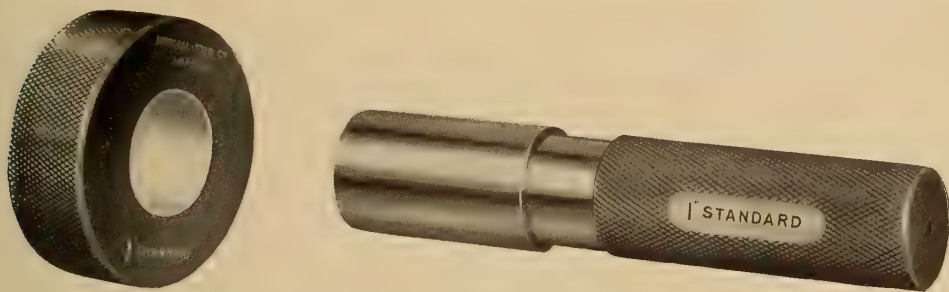
two ends of the same connecting rod, which work in widely different temperatures, the crank-pin cool, the crosshead end warm by conduction from the hot piston rod, it is quite evident that allowance has to be made for expansion differing in extent even for different parts of the same thing. We take little note of these matters on paper,—a few minutes' work with a scraper while erecting the engine makes all the difference,—but still, dead running fits will not do. The pin in the hole, the die in the link, the crosshead in its slides,—all these, whether we admit it or not, must differ from their normal dimensions if they are going to run successfully. Again, in a trunk bed engine the slide surfaces are bored out

timate connection with the piston rod:

A large engine would not run for five minutes under such conditions, and the fitter's scraper is again called into requisition to effect the parallelism of the slides under working conditions.

These instances are only a few out of the many which occur throughout the engine, and many an inspector's note-book will record vexatious delays and stoppages during the first few days of a new engine's career, directly traceable to neglect of a proper allowance for the expansion which takes place under working conditions.

We now enter upon another stage, that of erection. Temporary founda-



A STANDARD EXTERNAL AND INTERNAL GAUGE. THE NEWALL ENGINEERING CO., LTD., WARRINGTON

or planed truly parallel. We can imagine the inspector gauging the bore and pronouncing it "dead true." What would happen if the engine were put to work with it so? The heat conveyed by conduction from the cylinder (of which the trunk probably forms the front end cover) enlarges the diametrical measurement of the bored-out slides by a variable amount. The same gauge, if now inserted, would be perceptibly slack at the end of the slide nearest the source of heat, while at the further end the dimensions would practically be unaltered. It follows that the crosshead, if accurately fitted when all was cold, would be too tight at one end and too slack at the other, the crosshead itself expanding slightly in diameter through its in-

tions, usually of timber barks piled crossways to the required height, and dimensions are put down in the erecting shop, and upon these the massive beds and cylinders are laid down, accurately levelled at their proper distance apart.

The lower segments of the main bearings are put in their places and the heavy crankshaft is carefully lowered into position, followed by the side and top segments and the caps of the main bearings.

Right through the axial line of each engine is now stretched a fine steel wire. One end of this wire originates from a small iron or steel bar placed diametrically across the bore of the cylinder at the back end, having a fine hole accurately drilled through its centre, the other end be-



A STANDARD END GAUGE., THE NEWALL ENGINEERING CO., LTD., WARRINGTON

ing carried by a temporary support some distance in front of the crank-pin when in its position of being furthest from the cylinder.

The object of these two lines, it is hardly necessary to say, is to ensure that the pair of engines are parallel and truly at right angles with the shaft. Their distance apart at the crank end is determined by the shaft itself as it lies in the bearings.

Each crank-pin in turn is now brought round to the line, which should accurately bisect it both at the extreme outward and the extreme inward positions. A long trammel or gauge, with one fixed and one sliding point, set to the exact dimensions from centre to centre of crank-pin, is now applied to the centres of cylinders at the back end, and their coincidence with the ascertained crank-pin measurement checked over and corrected, if necessary.

Here is a case where a pedantic insistence upon the exact dimensions from centre to centre would be out of place. Supposing the engine were specified to be 16-foot centres, it is an absolutely immaterial error if, when the engine is put down for erection, they should be a shade more or less than that. But it is vastly important that they should be dead parallel. It is, if possible, more important still that the shaft should be dead square with the centre lines of the engines, and, provided these objects are attained, the precise distance apart is of little moment.

The engine beds being now supposed in position, with a visible tangible axis in the shape of the steel wire passing through each, there are one or two other matters to be de-

termined before the erection can be proceeded with. The inspector must not take it for granted, for example, that the guides are in a straight line with the cylinders. If they are trunk guides bolted directly to the cylinder flanges, the strong probability exists that the track of the cross-head and the track of the piston run in absolute agreement. But it must be demonstrated to him in this wise:—

The bore of the cylinder (which, it will be remembered, at its back end carries a cross-bar, with a wire passing through its exact centre) can be shown by the indications of a large caliper-gauge to be truly parallel with the wire throughout. It can also be demonstrated that the wire passes through the exact centre of the piston rod hole and of the stuffing box by the same means.

The crosshead being in position, the wire naturally passes through its centre hole (into which the piston rod will be cotted later on), and by moving the crosshead from end to end of the slides and calipering from the line at each end any lateral deviation from the line of the wire will be easily detected. It is absolutely essential for the quiet and successful running of the engine that all these points be rigidly correct.

It is to be observed that we have mentioned lateral deviation, or a departure from the true path in a horizontal plane only, for the abstract mathematical truth enunciated by Whewell:—

“There is no force, however great,

Can stretch a cord, however fine,
Into an horizontal line

That shall be absolutely straight.”

holds in practice, as well as in theory, and other means for detecting variation in a vertical plane must be adopted.

A sensitive spirit-level, set in a long cast-iron base truly planed on bottom and edges, is laid inside the cylinders, and again upon the lower slide surface. If the indications of the bubble are alike in both positions, it may be taken as affording the requisite assurance.

The inspector, in all probability, having satisfied himself that the engines are in line, will now defer any further investigations until he receives an advice from the contractor that the engines are fully erected. His final attendance at the works in respect of this particular contract, a few days later it may be, will find the engine completely erected, with all the hundreds of details, which hitherto he has but caught a transient glimpse of in his walks through the different departments, assembled and in position.

Long before this, however, he will have formed an idea from his own observation as to how far it will be desirable to examine closely into details, with the object of picking up any faulty workmanship, and will at this stage either carefully look over every part in turn on the watch for defects, or, as is most frequently the case, he will content himself with a comprehensive look around, knowing the character of the place and the methods of supervision in force.

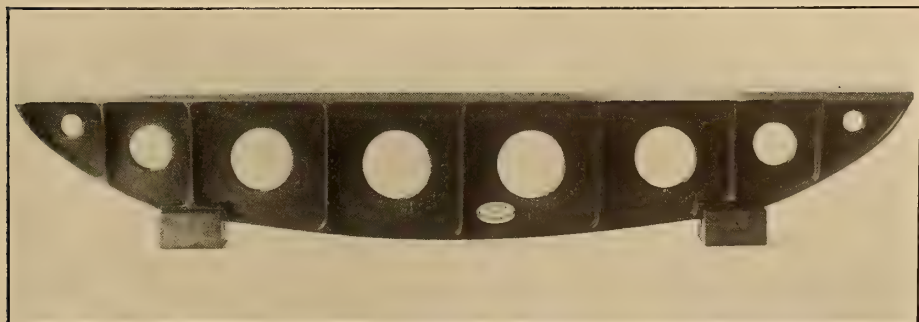
Supposing that it is not intended

to turn the engine round by its own steam at the contractor's works, there are still one or two final tests to make which the inspector should supervise before he leaves.

Means being at hand for turning the crankshaft slowly round, he should have the brasses removed from the large end of each connecting rod and ascertain for himself that, both at the inward and outward extremities of the stroke, the connecting rod (still cotted up to the crosshead pin) points perfectly "fair" for the centre of the crank-pin. Next the performance should be reversed. The large end brasses are cotted (or bolted, as the case may be) upon the crank-pin and the small end uncoupled. The crank-pin being successively turned to the four points in the revolution, "in," "out," "top" and "bottom," the free end of the connecting rod, when the crosshead is brought up to it, should be fair to enter without needing to be sprung sideways.

This is a convincing test of the squareness of the engine and of the truth of the crank-pin.

Again, there is the valve gear. Whether it be of the Corliss, the drop valve, or any other variety, tripped or controlled by a governor, it is the inspector's duty to see, first of all, when the governor sleeve is at a height a little above the position due to the normal speed of the engine, that it trips the gear at zero, or, in other words, cuts off the steam at the beginning of the stroke. When



A STANDARD STRAIGHT EDGE. THE NEWALL ENGINEERING CO., LTD., WARRINGTON

the governor sleeve is at its lowest the gear should trip at or beyond the maximum admission-point named in the specification.

To ascertain the points of cut-off, the path of the crosshead should be temporarily marked in eighths, or tenths, of the total stroke, and the observer, as the crankshaft is slowly revolved by hand or by the barring engine, keeping his eye upon the movement of the crosshead, will hear the click indicating the release of the valve gear, and can determine the point of cut-off.

It should be remembered, however, that when the engine is at work the rapid motion of the piston will overrun the valve motion to a certain extent, so that the actual operation of the valve gear is later all around

than appears from a slow movement.

Finally, there are a multitude of small fittings in the shape of special lubricators, drains, relief valves, cocks, steam traps, oil trays, and the like, which the inspector will have to see are not omitted. He should satisfy himself that these minor, though often very troublesome, matters are in order, and, specification in hand, should once more go through the whole of the description, identifying and checking off each item as he sees it before him on the engine and verifying the dimensions.

This practically concludes the business of inspection at the contractor's works. The steam tests, whether a preliminary trial run takes place in the erecting shop or not, will have to be dealt with in a succeeding article.





Current Topics

AN important sequence of the recent elections in Germany will probably be a more definite programme for the increase in the naval strength of the Empire. The hands of the government have been strengthened to such an extent that it appears altogether probable that early steps will be taken to bring the naval power of the German Empire to a point more nearly commensurate with its military position.

Under these circumstances the important paper of Mr. Hurd, which appears elsewhere in this issue, demands especial attention. Mr. Hurd shows very clearly that the naval strength of Germany, as compared with that of Great Britain, is almost obsolete, and that the American Navy is in a much more modern condition than that of Germany. He also points out that the task of bringing the sea power of Germany up to a modern status depends almost as much upon the provision of adequate harbour facilities as it does upon the building of larger and more powerful battleships.

As Mr. Hurd points out, the present limitations upon the size of German battleships are those of the Kiel canal and the ports of the Baltic and the North Sea, so that the combined efforts of the civil and the mechani-

cal engineer will be required, as well as those of the naval architect, before the natural difficulties of the situation can be overcome.

It is interesting to note at the present time some historical matters in connection with the relation of marine development and national power.

It is just one hundred years since Fulton started successful steam navigation by inaugurating a regular service between New York and Albany on the waters of the Hudson. Yet, it was four years before the first trip of the *Clermont* that Fulton laid before Napoleon a complete plan for the transport of his army across the Channel from Boulogne, under conditions which would have made the battle of Trafalgar an impossibility and the French invasion of England a reality. If Napoleon had decided the matter upon his own judgment instead of referring Fulton's plans to a committee of scientists, it is altogether probable that France would have had a steam navy before any other power at the very time when her military strength was also at its greatest.

Great Britain had also neglected a

similar opportunity, since Symington had constructed the *Charlotte Dundas* as early as 1802, and so both sides in the great struggle, which ended only at Waterloo, missed possession of the most powerful weapon which the engineer had ready for them.

To-day it is possible that similar oversights may be made. To the officialdom of the beginning of the nineteenth century, steam navigation doubtless appeared as uncertain and impracticable as aerial navigation does to the military powers of the beginning of the twentieth century, and it is a noteworthy fact that one of the committee who rejected Fulton's plans for Napoleon was Montgolfier, the inventor of the balloon.

That it is necessary for a nation to be equipped with the latest products of the applied science of engineering as a means of defense is generally admitted, but the immense importance of possessing the very latest methods of control of the great sources of power in nature at the earliest possible moment is not appreciated as forcibly as it should be. The importance of time in striking the first blow is well understood, but the still greater value of the first possession of the power with which to strike the blow cannot be too strongly impressed.

Since the days of Symington and Fulton, the work of the engineer has developed with an acceleration which has not permitted even an estimate, and the prolongation of the curve cannot safely be determined. Nevertheless, that nation which avails itself earliest of the power which the engineer is daily extending is the nation which can command peace at home and respect abroad.

THE question of congestion in great cities is one of the problems for the solution of which engineering methods are held responsible, but to engineering methods must be added such a broad view of

social conditions as may enable that solution to be something more than a palliative. Ever since the introduction of mechanical traction, steam, cable, electrical, the large cities of the world have been endeavouring to find some mechanical method of relief from the concentration of humanity within circumscribed limits, only to find that the greater the facilities for transportation the denser the congestion becomes.

Doubtless much of this is due to the gregarious nature of mankind, but it should be the part of the engineer so to use the facilities at his disposal as to meet the desire of men for association with a minimum of discomfort and inconvenience. That the best use is not always made of the facilities of transport is evident from the crowded state of the older portions of many large cities. Instead of attempting to relieve this congestion in a rational manner, some of the latest systems of municipal transportation appear to have been so arranged as to increase the very congestion they were intended to abate.

Thus, in the construction of the New York Subway, the provision of four tracks, to permit the operation of express trains, was heralded as a means of enabling the population density to be materially reduced, instead of which, both accommodation and express trains are crowded to the point of excessive discomfort within a year from the date of opening, and no prospect of relief seems possible with the equipment from which so much was expected.

An examination of some of the causes of the congestion may lead to suggestions for a partial remedy, at least. The greatest crowding of the express trains appears in the portion of the run from the lower part of the city about one-half the way uptown, showing that a large proportion of the passengers still reside in the older and more densely populated part of the metropolis. By providing facilities for reaching this older resi-

dence portion from the business district, the subway has simply added to the congestion which it was intended to relieve. Suppose, now, that the express service had been so arranged that, after a few stops in the lower business district, the trains were operated at high speed and with no stops until the extreme upper portion of the city, and even the suburbs to the north, were reached, there would be offered a strong inducement for people to leave the crowded parts of the middle residence portion and to spread their residence over a wide area of large possibilities for comfort and no loss of time in transport.

The older portion of the city would be no worse off than it was before the construction of the subway, but really much better served, since it would have the subway local trains added to the elevated and surface cars, and its population, becoming less crowded by the migration of a portion of its population to the area opened up by the high-speed, long-distance express service, would be adequately cared for.

With the increasing number of tall office buildings the congestion of the business district must be expected to continue, but this need not involve a corresponding crowding of the residence districts if the fundamental question of the wide and rapid dispersion of the population to an open residence section be made the controlling factor in arranging the system of operation.

At the present time there is under consideration the location of express stations upon a new line of north and south subway, and instead of deciding this essential element in successful operation by the above considerations of dispersion, it appears as if the desire for further concentration may be permitted to rule. Such a short-sighted view of a great municipal problem can only lead to a failure to relieve congestion by neglecting one of the most effective means for the solution of the problem. Instead of making it convenient for

people to accumulate where there are altogether too many of them already, it should be made rather unsatisfactory for them to crowd in the old locations, but extremely convenient for them to go directly from their places of business to predetermined areas where there is ample room. It has been said, in discussing another engineering problem, that of the distribution of air, that wind is much like a rope, in that it can readily be drawn, where it would be very difficult to push it, and the same is true of humanity. By providing lines of least resistance in the directions into which it is desired to direct population, large masses of people may be dispersed over a wide area, without offering material obstacles to the advantages, commercial and social, of close association, but the whole scheme must be planned beforehand, and not left to the selfish administration of individual interests.

SINCE the subject of the construction of a channel tunnel has been revived there has come along with it all the various opposing views, which are based upon a fear that the advantages of geographical insulation will be lost. To assume that the abandonment of the tunnel scheme will insure the permanence of that insulation, however, is not altogether warranted, and perhaps it might be better to consider what changes must be made when Great Britain has to face the inevitable alteration in her relations to the rest of the world. Already the question of unhampered commercial relations with other nations has been met, and few will deny that to the consequent freedom of trade the British islands owe much of their present commanding position. Personal and physical freedom of movement is bound to come before very long, if not under the sea, certainly over it, and any feeling of special security which depends upon the mere existence of a

turbulent body of water, less than 30 miles in width, must surely fade before the coming control of navigation through the air. Under such circumstances it seems as if it should require stronger arguments than those based upon the necessity for maintaining isolation to lead to the abandonment of the piercing of the proposed channel tunnel, for when the feeling of apprehension is once overcome it seems as if the advantages of continuous railway communication with the Continent should outweigh any other considerations.

THERE is very little doubt that the foundry has set the standard of excellence for electric cranes. Mr. Harry Sawyer, in support of this view, recently pointed out, in a paper read before the American Foundrymen's Association, that while some shops and mills may have heavier loads to handle and require greater speed, the crane manufacturer recognizes that the perfect control required in the foundry represents a higher state of development than mere requirements of capacity and speed. It should not be understood that good control is not required in mills and shops, particularly the latter; but, as a rule, the requirements of the foundry are much more exacting. The conditions under which a foundry crane is operated are less favourable to continued good service than the conditions in a machine shop. It is more subject to overload, and the dirt and dust necessitate more careful attention; furthermore, the men directly responsible are usually less familiar with machinery, with the result that the crane often does not have the care that it should. It is a mistake to assume that a crane which does the work of an army of labourers can safely be handled and cared for by one of that class. The importance of employing only thor-

oughly competent and conscientious operators, and keeping the cranes in perfect repair cannot be too strongly urged. Prompt attention will reduce the total cost of repairs, and the extra cost of careful and competent men will be saved many times in the more constant service and longer life of the crane.

AT the Brussels Congress of the International Association for Testing Materials there was resumed a work which has been somewhat interrupted during the past two years, both on account of the postponement of the proposed meeting at St. Petersburg, by reason of the war, and also because of the death of the president and founder of the association, Professor Ludwig von Tetmajer. In the meantime, there have grown up active local institutions both in Great Britain and in the United States, such as the American Society for Testing Materials, the Engineering Standards Committee, the National Physical Laboratory, etc., so that the conditions are materially changed.

Nevertheless, the original work of the association remains, the unification of methods of testing materials for all countries, including such systematization as shall render tests strictly comparable, wherever they may be made, and it is to be hoped that in this important work the association may be sustained and carried forward to final success.

At the recent convention there were presented papers upon the uniform nomenclature of iron and steel, together with a number of reports relating to the establishment of international specifications.

The reports upon the unification of methods of testing cover the testing of iron, alloys, and hydraulic mortars, and these will form subjects for further detailed criticism and comment.



From Other Points of View

Modern Factories

The "Iron Age."

TO say that a plant is modern does not give it the distinction it once did, for many new plants now deserve to be so termed. Factories are no longer built and equipped in the cheapest manner possible. In planning a new plant nowadays more time is often spent in working out details before starting to build than is taken up afterward in actual construction, and first cost is deemed secondary to means of producing economically. Another consideration which has become of prime importance, where formerly it seemed to be ignored, is the probable future growth. Few plants, if any, are put up to-day without providing to extend them whenever it becomes desirable, and extensions are designed to fit into the original scheme. In a measure, it is the unit or sectional bookcase idea carried into factory construction. Each factor in the general plan is simply extended. The buildings are added to usually on one end, or sometimes a duplicate parallels or continues its predecessor, being practically a counterpart in design and equipment of the corresponding older building. The industrial railroads, spurs from contiguous railroads (for

plants are now seldom situated with other than intimate access to transporting mediums), and in general all handling facilities are so designed that their range of action may be increased almost as simply as one block may be piled on another. The power plant when first laid down is located where it will remain substantially in the center of the system whatever the direction of expansion, and it usually allows space for at least a doubling of the equipment before a larger building will be required. In the shop tools may need some rearrangement, but this contingency is presupposed, and foundations, power connections, etc., all allow for the easiest accomplishing of rearrangement. The limitations line shafts imposed no longer exist; individual motor drive allows unlimited latitude in locating machines, and even group drive but slightly restricts. The drafting room, pattern shop, foundry, machine shop and power house, individually or simultaneously, may be increased in capacity, but at no stage in the gradual growth is the harmonious operation or appearance of the plant as a whole impaired.

Besides providing for expansion without complication, a modern manufacturing plant, in the present accepted sense of the term, must pro-

vide for the following: Convenient shipping facilities, systematic progressive handling of the material through the works, fireproof construction of the buildings, ample lighting—artificial and natural—and ample heating and ventilating, and, finally, and, above all, economical tools, by which is meant not necessarily those with the most refinements, but those which for the total amount represented in interest on the investment, depreciation and running expense produce the most work in the least time.

What has been said above in general applies to all factories for the production of machinery and machine tools, an example of which is described in the initial article in this issue, but it would hardly be appropriate to discuss the subject without some reference to plants essentially for products of a special nature wherein the art of manufacture probably has not as yet attained its highest development and radical changes in the equipment occasionally become desirable. It is the natural tendency to build a containing structure of more or less permanent character and suited to the accommodation of the machinery which it is then intended to install. That this is a mistake is realized when the form or size of the building prevents the adoption of improved machinery and processes. It then becomes imperative to rebuild and at an expense often almost prohibitive. Profiting by this experience designers of such plants are now inclined to take the attitude that the equipment is not merely initially but always of first importance, and the building is regarded as only a protection to be constructed as cheaply and simply as consistent with convenience and comfort and preferably of a type that may be easily replaced entirely if necessary, but if possible with the use of most of the older material in the rebuilding. From this standpoint ornate design and unnecessary stability are useless extravagances.

Theory and Practice in Engineering

From an Address by Mr. W. E. Symons at Purdue University.

AS a general proposition we are the product of our environment; it is also true that we have much to do in shaping our environment for good or bad, therefore, the plea of a practical man that he could not or cannot secure an education, or of the educated man that he could not or cannot acquire any practical knowledge, is not entitled to any consideration, except in a few cases with the first mentioned class, where poverty renders it prohibitive.

These pleas usually being based upon either ignorance, prejudice, pride, vanity, feeling of superiority, or that well-known malady of the human race commonly called "laziness." Most men who contend there is little or no benefit to be derived from practical experience belong in the incurable ward of those afflicted with the latter disease, and, as a rule, are not even good theorists.

To the man who is neither controlled nor afflicted with any of the above influences or ailments, and will wisely and harmoniously combine theory and practice, there is a broad field of application, which is not only inviting, but insures success, while in the same field of activity, either of the other specialists can reasonably anticipate slow progress, or complete failure.

In modern shop organization, the theorist can and does perfect plans with respect to matters subject to solution by engineering rules or laws, that the practical man is not qualified to handle; in their execution, however, many beautifully worked-out plans have been properly condemned as impossible by a man who scarcely knew the multiplication table. Propositions involving millions, that are theoretically correct, absolutely so, are sometimes a practical impossibility.

The same is equally true in the matter of shop economics, these two

being practically synonymous terms.

In the matter of the extent to which manufacturing methods can be applied, this is a problem wherein the relative value of engineering or practical knowledge is necessary in its solution should be governed entirely by the size or capacity of the shop or plant; small and unimportant shops or round-houses are usually and sometimes necessarily, operated in a very unsystematic and seemingly extravagant manner; any competent engineer would say shamefully inefficient with wanton waste.

It is, therefore, a poor place for engineering talent. In the large shop, however, where heavy rebuilding and new work is carried on, together with finished material for shipment to outside points, and the work is not interrupted by round-house demands, manufacturing methods can and should prevail, and here the engineer is in his element, in fact his knowledge is essential to its success.

Machine-Shop Illumination

"The Engineer."

SOME difference of opinion still exists amongst engineers with regard to the rival claims of gas and electricity, even for the purpose of lighting works in which electric current is used for power distribution; and several recently equipped engineering undertakings having electrical facilities of this nature have adopted the high or low-pressure gas system. In low-pitched buildings a very efficient and cheap light can be obtained in this manner, and the amount of attention required to replace mantles, etc., is less than for arc lamps. At the same time, the latter system is slightly cheaper, and the possibilities of future improvements are much greater than is the case with gas.

Where electric arc lamps are used current is sometimes taken direct from the bus-bars and distributed by

a separate set of mains to those supplying power, and this plan is desirable when the power circuits supply motors for heavy machine tools and powerful overhead cranes, as the sudden demands for currents, especially for the latter, are certain to cause fluctuations in the lighting. But in works where the machines are small and driven in groups from line shafts, there is no reason why current for power and lighting should not be taken from the same distributing mains. Also in isolated buildings such as the smithy, brass foundry, etc., one pair of cables and distributing board may be used for both lighting and power.

The lamps for low-pitched works are usually of the 10-ampere size, and when used with clear globes or plain lanterns, each lamp will light up 800 square feet of floor space sufficiently for ordinary work. Opal globes are to be preferred for small work, but if they are used the floor space for each lamp should be limited to 500 square feet. For very fine work, or for lighting large offices, excellent results may be obtained from inverted arc lamps spaced about 20 feet to 25 feet apart. If the lighting in such works be carried out as indicated above, and the roof and walls be kept fairly white, no incandescent lamps should be required excepting in the offices. The lighting of lofty bays of considerable width involves more powerful lamps than have been described above. The roof will give little help in diffusing the light, and the traveling cranes often prevent the most effective spacing of the lamps. The latter are usually suspended from brackets along the side walls and under the crane runways where two bays adjoin each other. Powerful flame arcs can also be used above the cranes in very high buildings. It is almost impossible to give general rules for lighting works of this description, but it may be mentioned that opalescent globes should be used, and the lamps may be of the 15 amperes size, spaced 30 feet to

40 feet apart. Works of moderate height can be, and, in fact, have been, lit satisfactorily by arc lamps only, and with flame lamps available for very high buildings, incandescent lighting for engineering works should be unnecessary in future.

Motor-Car Designing

"Engineering."

IF a man of moderate means is asked why he hesitates to buy a car and go in for motoring, he will in general give one or other of two reasons: either that motor cars cost too much, or that they give too much trouble. As both objections are matters of degree, their force varies inversely with the wealth and enthusiasm of different individuals; but there can be no doubt that the development of the motor-car industry would be immensely increased could the initial cost of cars be lowered, and the purchaser feel a reasonable certainty that no expensive "happenings" would ever take place on the road. When saying this, we do not underrate for a moment the enormous improvement that has taken place in motor cars of recent years. A stranded or derelict car is no longer a common object of the roadside, and one may now travel for thousands of miles without ever having to open the tool-box. Further, prices have come down considerably; and concurrently, moreover, with a great increase in the value given for money, for the car of to-day is a far more complex piece of mechanism than the car of a few years ago.

Having given the motor-car manufacturers this much credit, we propose to treat them to a little disparagement as an incentive to further improvements. We trust they will believe that our criticism is as painful to us as to them, and uttered, not because we love them less, but that we love good design more. We have every sympathy with self-propelled vehicles, but none with bad engineering, wherever it may be found.

If it can be shown, as we believe it can, that with a proper attention to mechanical and manufacturing considerations better cars could be made at a less cost, we are serving the best interests of the industry by raising the question of the design of the modern car.

The general type of the motor car was developed in France, during the days when self-propelled vehicles in this country had to be heralded by a pedestrian with a red flag. Hence, naturally, the earliest British cars followed along the line set by the French designers. Now, as pioneers the French engineers are admirable, but when it comes to commercial manufacturing their designs are far from being worthy of slavish imitation. It has always been said to the credit of the British designer that he effected improvements by simplifications and omissions, whereas foreign improvements were signalized by increased complexity. Had British engineering instincts been allowed full play, and the foreign-built motor car been regarded as a type instead of being copied as a model, we should now hold a commanding position in the industry. But the haste of the British manufacturer to get a car on the market, and his natural inclination to suppose that it would be better for him to follow established practice first, and to improve on it afterwards, has prevented the "all-British" cars in general from being altogether creditable to the engineering practice of this country. In material and workmanship they are fully equal to the pick of the French and Italian cars, but in the details of design they are still too much under the influence of Continental ideas of engineering to do justice to their builders. However, now that our motor-car manufacturers include in their number some firms who have previously gained world-wide reputations as engine and machinery builders, we have every confidence that the British car will soon be typical of sound engineering practice.

HENRY C. SERGEANT

A BIOGRAPHICAL SKETCH

WITH the death of Henry Clark Sergeant there passed away a typical American inventor, a man whose work resulted both in mechanical and commercial success. Mr. Sergeant is best known for his connection with the development of the modern rock drill, but his activity in other departments of work shows the versatility of the man.

Born seventy-two years ago, at Rochester, N. Y., Mr. Sergeant passed from the common school into the workshop, where his inventive faculty soon showed itself. His first ventures in invention related to the making of hubs, spokes and felloes of wagon wheels, and these were rapidly followed by improvements in boiler feeders, marine-engine governors, gas regulators, brick machines, water meters, and a like variety of appliances.

In the early seventies Mr. Sergeant was running a machine shop in New York City when Simon Ingersoll came to him with the drawings for the first Ingersoll rock drill, as then existing only on paper. Mr. Sergeant was immediately attracted by the machine and its possibilities, and, although it is now impossible to tell how much he contributed to the development and success of the machine, it is certain that at least one patent was issued jointly to Ingersoll and Sergeant, and the Ingersoll Drill Company was formed to build and introduce the apparatus.

The first drills were arranged to be operated by steam, but the advantages of compressed air, especially for mining and tunnel work, led Mr. Sergeant to devote himself to the production of a suitable air compressor for use in connection with the

business of the company. The growth of this department of the business led to the formation of the works of Sergeant and Cullingworth, with shops at Twenty-second street and Second avenue, New York.

It was during these early years that Mr. Sergeant developed his water meter improvements, two of these patents being taken out jointly with Mr. José F. De Navarro.

After some mining ventures in Colorado Mr. Sergeant returned to the East, having developed a new rock drill, to build which he organized the Sergeant Drill Company at Bridgeport in 1886, and two years later he again joined Mr. Ingersoll in New York to form the Ingersoll-Sergeant Drill Company. With one period of absence, mainly in Europe, Mr. Sergeant devoted practically all his time to invention in the interest of the company, improving its products in many ways, the most notable inventions being the Sergeant "Auxiliary" and "Arc" valves, "Tappet" rock drills, "Release Rotation" for rock drills, and "Piston Inlet Valves" for air compressors, all of which are in successful use to-day. Mr. Sergeant was also the originator of many new ideas in stone channeling, coal undercutting, and associated lines of work.

During the remainder of his life Mr. Sergeant gave his efforts to the development of the business of the Ingersoll-Sergeant Company, which prospered continually. The works at Easton, Pa., were occupied in 1873, and ten years later the large shops at Phillipsburg were found necessary for the growing business, the latest development being the consolidation of the two foremost but competing

companies in the world in this line by the formation of the Ingersoll-Rand Company. After this combination Mr. Sergeant continued his active interest in the work until failing health compelled him to withdraw about two years ago, his health being impaired by rheumatism, although his death was primarily due to paralysis.

Although Mr. Sergeant left his mark as an inventor on many lines of work, his name will always be associated with the development of the rock drill, the machine without

which such enterprises as the Chicago Drainage Canal, the Niagara Power development, the new Croton Aqueduct, the New York Subway, the Panama Canal, and many other undertakings would not have been commercially possible. When to these are added the enormous railway and mining interests over the world which have been advanced by the development of the rock drill, it will be realized that to the work of Henry C. Sergeant the world is enormously indebted.





RUDOLPH DIESEL

INVENTOR OF THE DIESEL HEAT MOTOR

SEE PAGE 560

INDEXED

CASSIER'S MAGAZINE

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THE CATARACT OF IGUAZU

A GREAT NATURAL SOURCE OF POWER IN THE HEART OF SOUTH AMERICA

By Henry Harley



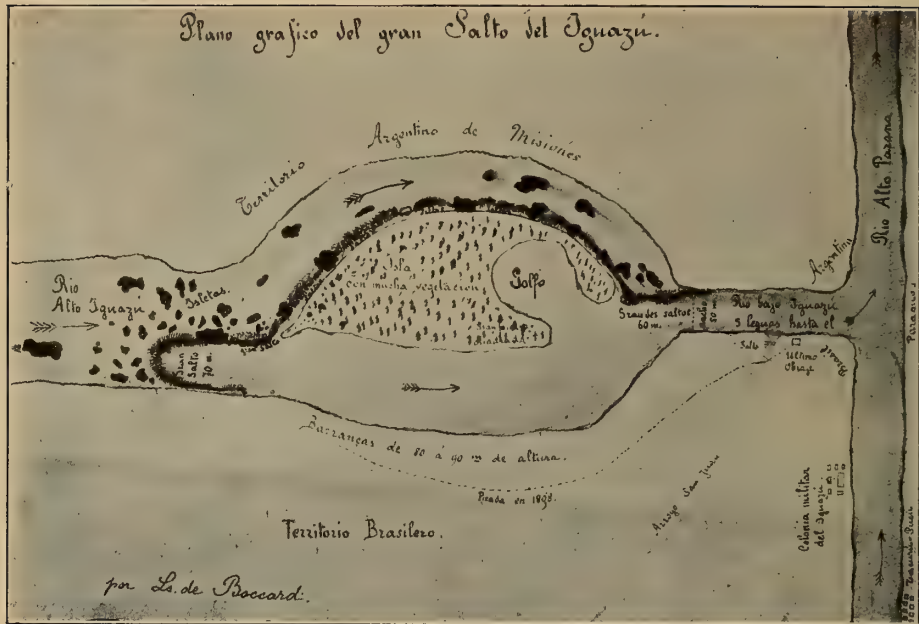
IGUAZU—THE CREST OF THE BRAZILIAN FALLS

NIAGARA has been harnessed and international limitations placed upon the amount of water which may hereafter be diverted from the river for the development of motive power. The Victoria Falls of the Zambesi are under course

of exploitation, the principal question in that respect now being the most suitable method for the long-distance transmission of the power of the falls, rather than the fact that it is to be developed. From North America and South Africa the engineer may now turn his eyes towards South America, and there consider the mighty source of power in Nature existing on the Upper Parana, at the junction of three great States, the Cataract of Iguazu, hitherto scarcely considered, but now entering upon a preliminary career as an attraction for tourists, prior to its inevitable development as one of the great hydro-electric power centres of the world.

The existence of a great cataract on the Upper Parana has doubtless been known to the Indians for an indefinite period, but the first authentic account is found in the "Cronica" of the Jesuit missionary Padre Lozano, forming a portion of the archives of the society, and written in the year 1767. After describing the upper waters of the Parana, and referring to the river Iguazu as a tributary, Padre Lozano proceeds:

"Of so strong a current is this river Iguazu that it may not be navi-



IGUAZU—AN EARLY JESUIT MAP OF THE FALLS

gated, and the reason thereof is, that at a distance of four leagues from its mouth (i. e., its junction with the Parana) it is cut from side to side by a precipice of exceeding height, where the waters are hurled in such a tumult that they may be heard three leagues away. And, moreover, this cliff has been to the Indians that dwell there as it were a natural defense, so that the bold assaults of Spanish valour have never penetrated to their retreat; nor indeed had any stranger set foot in the land until it was conquered to the service of Christ by the arms of the Evangelist and the unfaltering courage of our Jesuit missionaries. Such is the force of this fall that from this single leap there is formed a fair cloud over it like a crown and which may be seen even from the banks of the Parana."

From the time of Padre Lozano until the development of railways and steamship service by British energy and capital, little has been known or said of the Falls of the Iguazu, but during the past few years the accessibility of the cataract has been ren-

dered easy, and with the fuller information available, not only the tourist but also the engineer and the capitalist may well become interested in the great falls.

Roughly speaking, the river Iguazu, a name derived from the Guarani words "Y"- "Guazu," "great waters," enters the Upper Parana at a distance of about 1500 miles from the mouth of the river on the Atlantic Coast, being at the junction of Argentina, Brazil, and Paraguay. The Iguazu rises in the Serra Catharina, the range forming a barrier between it and the Atlantic, so that, although its origin is only about 30 miles from the ocean, its flow is westward, until its waters enter the Alto Parana, with which they flow southward until they reach the Atlantic through the river Plate, more than a thousand miles south of their source. Draining the watershed of the Serra Catharina and the Serra Geral, forming the greater part of the State of Santa Catharina, in Brazil, the Iguazu forms one of the important tributaries of the Alto Parana and constitutes the boundary



IGUAZU—THE CENTRAL PORTION OF THE GREAT HEMICYCLE AND THE BASALT LEDGE WHICH DIVIDES THE FALL INTO TWO LEAPS OF 100 FEET EACH



IGUAZU—THE BRAZILIAN FALLS. VIEW THROUGH THE LOWER GORGE



IGUAZU—THE GREAT ARGENTINE FALLS



IGUAZU—PLAN OF THE FALLS AND RAPIDS

between Argentina and Brazil. Its upper course winds in and out among the hills and broken country until within about 12 miles of its junction with the Parana it makes a bend of more than a right angle, and on this bend the entrance into a narrow gorge creates the falls.

On the inner side of the bend, the Brazilian bank, the greater part of the water makes a clear leap of 210 feet into the gorge below, this forming what is called the Brazilian Falls. The entire volume of the water, however, is not intercepted at this point, the channel continuing on around the elbow of the bend, past a number of small islands, and past a larger island, which, as at Niagara, divides the cataract, and then forms the Argentine Falls, in two leaps of about 100 feet each. Measured directly across from the beginning of the Brazilian pit to the further edge of the Argentine Falls, the distance is 6000 feet, but taken around the broken contour of the edge of the cliff, the length is about 10,000 feet. When, as in the rainy season, the river is swollen, the small islands are submerged, and the full width, with the exception of the central island, is one mass of cataract. Just above the

falls the actual width of the river is about 3000 feet, while the gorge below is a narrow canyon about 400 feet wide. During the tropical rains the flood rise in the wide upper stream is about 10 feet, while in the so-called "Devil's Canyon" in the gorge below there is sometimes as much as 120 feet difference in level between high and low water.

Naturally the comparison of the Falls of Iguazu is with Niagara, and data for a partial comparison are at least available. In the case of Niagara, the total length at the edge of the falls is given as 4770 feet, including Goat Island, the actual contour of the falls being 3010 feet. The height varies from 158 to 167 feet, being highest on the American side. Comparing these dimensions, the Falls of Iguazu are more than double the width of Niagara, and about one-third higher. The estimated flow over Niagara is given as 15,000,000 cubic feet per minute, but at Iguazu no reliable measurements are available. Doubtless the flow varies greatly at different seasons, and we have already noted the rise which occurs in the river during the rainy season. The flow at Niagara varies also, and its discharge is subject to



IGUAZU—THE BASALT FORMATION BELOW THE ARGENTINE FALLS

the effects of a northern winter, from which the tropical waters of the Iguazu are free.

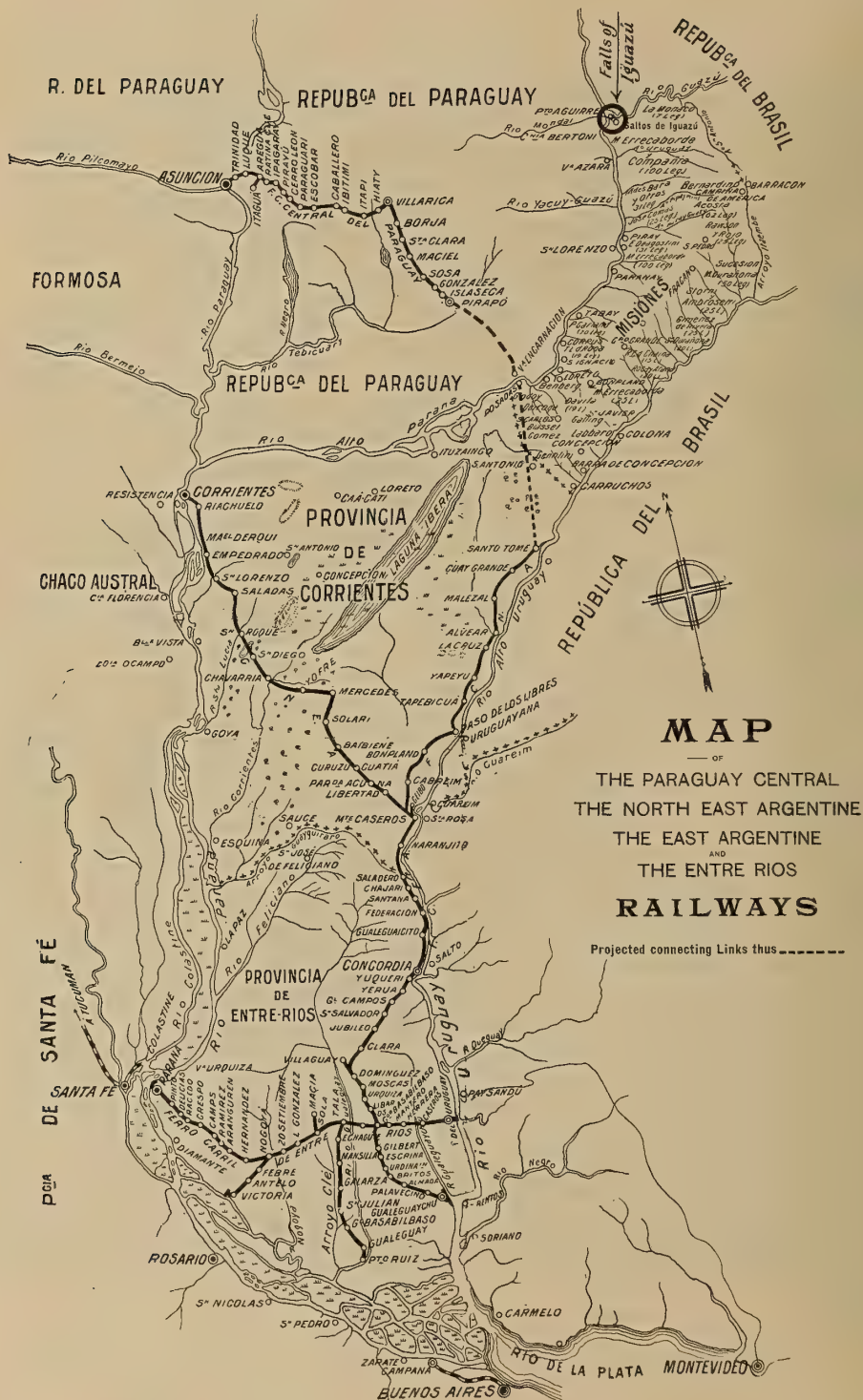
In addition to the great power site available at the Iguazu Falls, there are other cataracts which would attract much attention were it not for the overpowering immensity of the great waterfall itself. On the Alto Parana, about 6 miles below the junction with the Iguazu, comes the river Nacunday from the Paraguayan side, and only a few hundred yards back of the junction are the Falls of Nacunday, a straight, uniform cataract, fully 50 feet in height and about 250 feet wide. Here is a natural water-power site, requiring only the installation of the power house and penstocks to enable thousands of horse-power to be developed and delivered to the surrounding country, a country wealthy in timber and natural resources, only awaiting capital and development. Again, on the Parana, 200 miles above the entrance of the Iguazu, there are the Falls of Guayra, while many lesser

waterfalls on the surrounding streams have given the whole district the name of the "land of waterfalls."

At the present time the Falls of Iguazu are reached from Buenos Aires by a trip of some twelve days' duration, combining river and railway travel, and forming an excursion which is certain to become increasingly attractive. The departure from Buenos Aires is made on the steamer upon the broad estuary called the River Plate, but really being the confluence of the Parana and the Uruguay, the boat proceeding up the Uruguay to the head of navigation at Concordia, from whence the Entre Rios Railway takes the passenger to Corrientes. The province of Entre Rios, as its name indicates, lies "between the rivers," the Uruguay and the Parana dividing as the traveler leaves the Plate and running parallel at a distance of about 150 miles apart, while between them lies the fertile rolling country, famous for its farms and cattle-raising industry. It is in this part of Argentina that the



IGUAZU—VIEW OF THE ARGENTINE FALL FROM THE DEVIL'S CANYON





THE FALLS OF NACUNDAY—ALTO PARANA



THE RUINS OF THE MISSIONARY CHURCH OF SAN IGNACIO

Hirsch colony is situated, at Santa Clara, covering more than two hundred square miles. The road passes from Entre Rios through the Province of Corrientes, the railway now becoming the Northeast Argentine Railway, the line leaving the Uruguay and running diagonally across the Province to the terminus at the town of Corrientes.

Corrientes, lying at the junction of three rivers, the Bermejo, the Paraguay, and the Alto Parana, is the starting point for the remainder of the river trip. The navigation of the upper reaches of the river is difficult, owing to the shifting nature of the bed, the sand banks changing with the changes of the current and demanding shallow draught steamers and careful navigation. At the rapids of Itati the slope of the river is about 30 feet in a little less than a mile, rendering the passage difficult and treacherous. For about 150 miles the river runs eastward, until at Posadas it again bends north-

ward and becomes the boundary between Paraguay and the Argentine Province of Misiones. This Province of Misiones, as its name indicates, was the seat of the efforts of the Missionary Fathers of the Order of Jesuits during the eighteenth century, and there are to-day many remains of the work of these devoted men in this part of Argentina. Misiones was really the headquarters of the missionary work of the Jesuits in South America, and from the records of the year 1752, it appears that there were in the Province thirty missions on the banks of the Uruguay and Parana, controlling more than 140,000 Guarani Indians.

All that remains of these missions is the ruins of some of the chapels and churches, the remains of one of these, the church of San Ignacio, being shown in the illustration, overgrown by the luxuriant vegetation of the forest. The industries of the Province of Misiones are already important, including the "yerba mate," or



THE RAPIDS OF GUAYRA ON THE PARANA, 200 MILES ABOVE IGUAZU. VIEW FROM THE PARAGUAYAN SIDE



THE FALLS OF SALTO, URUGUAY

There is here ample power for the towns of Concordia and Salto

Paraguayan tea, Indian corn, arrow-root, and lumber. About one-fifth of its 10,000 miles area is clear agricultural land, the remainder being valuable forests of cedar, pine, laurel, and other fine timber, only awaiting utilization for the finest of woodwork. The terminus of the steamboat journey is Port Aguirre, from whence the traveler makes the brief final stage of the journey on mule-back through the forest to the falls.

Owing to the luxuriant vegetation, the forest view of the falls is broken into a number of interrupted prospects, and the absence of any bridge to the Brazilian side prevents as complete a view of the whole as might be desired. This, together with other improvements, will doubtless be supplied, in connection with a complete plan, already laid out, for the conversion of the surrounding country

into a park. There is, however, a pathway which leads out to a deep barranca facing the cascades, and the illustrations show to what an extent the great cataract may be seen, even under existing conditions.

The route which has thus been described is much longer than the actual distance of the cataract from the sea. From Iguazu directly east, through Curitiba to Paranagua, on the Atlantic coast, is about 400 miles, and a portion of this distance is already covered by railway. If present methods of long-distance electrical transmission of energy are developed to the extent which has been considered in connection with the utilization of the power of the Zambesi, it should be possible to send the power of the Falls of Iguazu over the 300 miles to Curitiba and possibly all the way to the coast.

WASTE GASES AS A SOURCE OF POWER FOR THE OPERATION OF ELECTRIC RAILWAYS

By F. E. Junge



THE object of this paper is to study the possibilities of utilizing, by efficient conversion, the waste gas energy which is liberated from the raw materials of the iron smelting and coal mining industries for generating the electric power required to transport by rail ore and coal from their respective mines to blast furnaces and coke ovens, and the finished goods to local markets. It is also proposed to analyze the possibilities of opening up the large undeveloped bodies of rich ore available in remote districts of the United States by improving and cheapening, through the utilization of such gases, transportation facilities, thus creating new independent iron-producing centers for the supply of those markets, which hitherto precluded the development of industries owing to the lack of suitable fuels.

The following remarks may serve to set forth the line of thought which commends a serious discussion of the above question. Assuming that the rate of growth of the demand for iron will, in the next fifteen years, not increase in accumulative ratio, but in proportion to that of the last fifteen years, then the iron industry of 1920 would call for fully 80,000,000 tons of iron ores and 40,000,000 tons of coke in excess of the quantities hitherto consumed in any single year. Raw materials cannot be produced ad libitum, but with a continuous consumption of nearly 120,-

000,000 tons annually, must inevitably decrease, and become exhausted sooner or later.

Referring to American conditions, it has been estimated that the reserve of iron ores in the Lake district (which produced in 1905 about 80 per cent. of the total iron ore output of the United States) available for future operations, amounts to 1,500,000,000 tons of ore, carrying over 50 per cent of metallic ores. The value of these ores, as well as of the coke that is used in the process of their transformation, is decreasing daily, while the cost of production on account of the increasing material and labor cost is getting higher every year. Since the almost exclusive concentration of operation to the one district may provoke a rapid exhaustion of the Lake ores, which would be fatal to the continued supremacy in the iron industry of the United States, it seems advisable to direct the distribution of pig iron production in due time to other territories, having comparatively virgin resources, and where markets for the disposal of finished goods are rapidly developing, as is the case in the Western States. The Rocky Mountain and Pacific States contain many large undeveloped bodies of ore, chiefly magnetite and hematite, but owing to the distance from fuel and markets and high transportation charges, less attention has been paid to their exploitation than they deserve.

The Lake Superior districts, where immense deposits of hematite occur, but fuel is scarce, owe their controlling power greatly to the very favorable conditions of natural transportation, the ore being shipped to fur-

naces in the Central and Eastern States via the water road of the Great Lakes, being delivered at \$3 and \$3.50 per ton. But since the metallic value of Lake ores has been constantly decreasing from 68 per cent. down to 50 per cent, the factor of transportation is even there gradually assuming a more serious aspect. In the Southeastern States, where iron and coal are more closely located, the small cost of transportation allows the ores to be delivered at the furnaces at a price much lower per unit of iron than the above, viz: at \$1.10 per ton. The difficulties offered in the Western districts by scanty fuel supply and high freight charges can be successfully overcome and the range of operation of blast furnace plants can be greatly extended and the cost of production largely reduced by increasing transportation facilities, or in other words, lowering the cost at which ores and coal can be delivered at the furnaces and coke ovens, respectively, and finished goods at the local markets.

The evolution of gas power in Europe has established efficient and reliable means to utilize profitably for the generation of heat and power the gases which are generated from the raw materials of the iron industry as a by-product, and which were formerly wasted. This means offers the desired possibility of reducing the cost of transportation to a very low figure. The reason why the power for operating an electric railway for the transportation of raw materials and finished goods through iron and coal mining districts or from one to the other, can be gained at such low cost, rests besides with technical details, with the fact that modern coal mines and coke ovens working with by-product recovering, as well as blast furnace plants and steel works, must, in order to work with maximum industrial economy, possess their own electric central station for generating their power to drive the various auxiliary machines like pumps, hoists, fans, motors, etc., all over the works. Prac-

tice obtained in continental iron works has proved beyond doubt that the application of gas engines, as prime movers in such central stations, is by far the most economical of all known methods, the total cost of operation having been reduced in actual practice to about one-third of the value of steam drive. By simply extending the capacity of the central stations, which is quite possible, by a judicious application and distribution of the uses of waste gases within the works, we can generate at no additional heat cost the entire energy, not only for transforming the original ore into marketable steel products, but also to transport the raw materials and finished products to their respective places of destination, provided that the latter fall within the commercial distribution radius of the furnace plant, coke ovens or coal mines or all of them.

It is a well-known fact which need not be here developed in detail, that of the total quantity of gas generated in a blast furnace plant about 50 per cent. is required for use within the plant, including losses at the furnace top and in pipings, viz: for driving blowing engines, heating blast stoves, operating the gas cleaning plant, and generating electric energy in the lighting station, while the rest, representing an amount of 25 H.P. per ton of pig iron produced every twenty-four hours, is available for outside purposes or sale.

Modern combined works often possess their own coal mines and coke ovens, where the coke is made which is later shipped to the furnace to be charged, together with the ores for smelting the latter. Assuming the consumption of only one ton of coke per ton of iron smelted, we need for a production of say 1200 tons a day, 1200 tons of coke. Figuring on an efficiency of transformation of 76 per cent., 1580 tons of coal are needed for making that coke. The total quantity of gas generated per ton of coking coal in Europe averages 27 cubic meters, so that 442,400 cubic

meters of coke oven gas are produced within twenty-four hours. About 60 per cent. hereof is used for heating the retorts, leaving 40 per cent., or 176,960 cubic metres, for other purposes. This gas has a calorific value of 4500 calories, and some 700 litres of it when burned in a gas engine are required for generating 1 horse-power hour. The total available energy of such a plant would therefore be 10,500 H. P. Of this amount, about 10 per cent. is used for driving plant auxiliaries, leaving 9500 H. P. available for sale.

If the coke ovens are situated near the steel works the gas may be used in the works for heating steel furnaces. In a plant of above capacity, this would mean 52,000 cubic metres of coke oven gas, replacing 39,000 kilograms of good coal, and absorbing one-third of the total surplus quantity of gas available (160,000 cubic metres). Without deducting the amount for above application, there are for every ton of coal transformed to coke in twenty-four hours, 6 H. P. available for other uses.

The development of modern gas producers has created a third and very powerful resource for the production of energy, in addition to what is gained as a by-product from furnaces and coke ovens. This is the utilization of inferior grades of fuel in coal mines, such as slack, residue, refuse and minerals, which drop from the conveyors and tipplers; in short, all that was formerly wasted. This material, which at the average contains not more than 20 per cent. of coal, is now fed directly to the producers. In the Von der Heydt coal mines at Saarbrücken, Germany, 2100 tons of culm are gasified per month in Jahns ring producers, giving a total of 40,000,000 B. T. U.; in other words, 2.2 pounds of waste generate 7140 B. T. U. Figuring on an average consumption of 10,000 B. T. U. per horse-power hour in gas engines, and deducting losses through natural deterioration and auxiliary requirements, 1 ton of culm generates 25

horse-power per twenty-four hours, which were formerly thrown away, but by the installment of such gas producers are now available for sale or other purposes.

Summarizing, we have in blast furnace plants 25 H. P. per ton of pig iron produced; in collieries, 6 H. P. per ton of raw coal, and in coal mines, 25 H. P. per ton of waste material per twenty-four hours, available for covering the transportation requirements in a combined plant.

It would now be quite easy to construct an academic case and prove by mathematical analysis that the power required for hauling the raw materials and finished goods of some imaginary iron smelting plant possessing its own ore and coal mines and collieries within its commercial distribution sphere, is fully covered from these resources, and without supplying additional fuel, that is, without extra heat cost. But calculations of this kind, unless based on actual conditions, are rarely of great value, as through the various theoretical assumptions that have to be made a number of uncertain quantities are introduced into the problem, which are apt to make the results of such an investigation rather problematical. So I prefer to here discuss some of the more technical possibilities of the proposed project.

Speaking first of the various uses to which the waste gas energy of the iron industry can be put to, I refer to a former paper on the "Utilization of Waste Gases,"* wherein I have set forth such considerations as occur when deciding about the various forms of application of the waste gases for heat or power purposes within the works. I shall now compare the technical prospects of selling the surplus power which is available in the iron industry in the form of electric energy, to local markets, against using it for the transportation of raw and finished goods on railways owned by a corporation or syn-

* "Power," January, 1907.

dicade, either transversing the iron and coal fields or running from coal mines to ore districts and the reverse.

The difficulty that confronts us in the first application is that only in rare cases will the blast furnace plant be located in the immediate vicinity of a large city or other industrial center, offering staple markets for the profitable sale of such energy. Unfortunately we cannot place the plants in a convenient neighborhood of towns or other communities, but we must build them either near the ore mines or near the fuel supply and markets. Therefore, we have in this case to first attract other industries to locate within our iron producing fields, in order to make them power producing fields as well, and we have to cater to their interests so that we may find an outlet and get remunerative returns for our surplus energy. Not so when we employ such power for railway transportation, which is a factor that must invariably be considered and solved regardless what are the local conditions and the geographical situation of the plant.

In assuming a favorable case, viz: that our blast furnace is located in the immediate vicinity of a large city to which it can sell electric power, then another complication arises. We must guarantee to our consumers, perhaps under heavy penalty, to deliver a certain amount of power regularly at all times during the season. It is known, however, that blast furnaces and coke ovens are subjected to certain unavoidable irregularities, owing largely to the quality and supply of the raw materials, to the working of the furnace, and to the condition of the pig iron market, which might require a banking of the furnaces, and to other variations which have a marked influence on the production of gas, affecting its quantity as well as its quality and making it extremely difficult to foretell whether of the total theoretical surplus power there will be enough available to cover the maximum demand of our consumers. It is therefore necessary

for the works management to introduce for the supply of outside markets a coefficient of safety; in other words, if we have two furnaces in an iron smelting plant, and no reserves in form of gas producers, it is safe to figure only on the available surplus power from the gas of one furnace. So, as conditions now stand in the United States, we have all our craving for economy, and with all the efficient engines at our disposal still to waste at least half of the precious gas energy by insufficient conversion, which cannot be utilized within the works. Here is where the enormous economy of the proposed application becomes apparent. We can foretell with sufficient accuracy what will be the amount of power required for transportation, but in fact, this is immaterial, for we can utilize all of our waste gas energy for hauling purposes, because consumption and production of energy are balancing each other. If times are bad no pig iron is made and fewer materials required, consequently less power is needed for converting and transporting them. If the furnaces are in constant operation, a constant amount of ore and coal is required and their transportation consumes the total quantity of power generated. Furthermore, even if the conditions were so stable as to allow in the first application the coefficient of safety to assume its maximum value; allowing all the available power to be delivered in form of electric energy to neighboring districts on the one hand, and to be utilized for operating our railway on the other, there would still be the question to be settled which of the two forms of application offers the higher load factor.

Speaking of existing conditions, the inner station load factor of iron and steel smelting plants is about 50 per cent. If an electric lighting plant is attached to the central station for the supply of a neighboring city, the load factor of the branch system is barely 25 per cent. and usually lower. The corresponding item of a large railway

plant is 65 per cent., and in our case by a judicious distribution of the rolling stock can be made 70 per cent. and even higher.

Finally, there is this great economical advantage about the proposed project, that it allows replacement of the steam locomotive by gas-driven central stations and sub-stations, located along the road, if the latter extends over a wide territory. Electrical apparatus have now been developed to such a state of perfection that in a well designed and carefully managed power station over 90 per cent. of the power in the engines is converted into electrical energy and delivered to the transmission system for the operation of cars. Of all the various items which have to be considered in the design of such power station for railway work, viz: the first cost, interest, depreciation, taxes, insurance, labor, supplies, repairs, and cost of fuel, the last named is the most important item of expense, frequently amounting to more than all other operating costs combined. Since the application of gas power has reduced this factor to one-half and even one-third of the value of steam-driven electrical central stations, it can be imagined what is the saving effected per ton mileage, compared to locomotive haulage.

Summarizing what has been said, it seems utterly absurd that a manufacturer who generates power as a by-product of operation, and requires constant energy for the transportation of his goods, should sell a small amount of such power to an unstable outside consumer at low profits and should waste the rest, and on the other hand should buy the energy for transporting such goods from an arbitrary producer at high prices and at a risk, instead of employing all available power for his own requirements, which guarantee him a constant consumption, stability of transportation conditions, and enormous savings.

Geographical and local conditions will, of course, greatly determine the commercial feasibility of any such

project. Things are most favorable, if one concern possesses ore and coal mines which are located at such distances that one power station at each end of the line, the one running on producer and coke oven and the other on blast furnace and producer gas, is sufficient for supplying energy over the whole territory without the employment of sub-stations. If this distance is too long, sub-stations must be arranged along the road which may preferably serve as collieries to transform some of the coal that is shipped from the East to coke, which is later used in the Western furnaces. However, it is useless to dwell at length on the elaboration of these local details, as concrete figures can only be given on concrete applications, and without having a definite case in view, the data submitted can only be regarded as speculative theory. I shall, therefore, rather point out some more of the commercial aspects of the proposed system.

Owing to the protective tariff, an efficient production in the iron industry of the United States and Germany,—which are now the two foremost iron producers in the world,—is only possible by combining in one hand, coal and ore mines, blast furnaces, steel plants, rolling mills, in short all that is necessary for converting the raw material into finished goods. To this same reason is due the enormous progress made in the iron industry of these two countries compared to England, where capitalists are justly reserved to invest large sums of money for improvements in the art of iron production, since owing to the free trade, every foreign producer can at any time throw any quantity of iron on the English market. In modern combined works of such magnitude as exist in the United States and Germany, all factors are therefore under control of the management of the trust or syndicate, except the factor of transportation, which in the first country is largely controlled by the railroad companies, in the second, by the government.

For various well-understood reasons, which are now being revealed to the eyes of the public, it is very desirable for the American iron industry to also lay hold on this factor, so as to be altogether independent of outside arbitrary measurements and certain of self-controlled stability of transportation facilities. If the iron industry would possess their own railroads for transporting their goods, or if ironmasters or owners of coke oven plants and coal mines would even (as power producers) deliver electrical energy to the railroads as consumers, they would control the situation of the iron market, instead of having to part with their profits in order to reduce tariff rates. That this view is also held by the executive circles of the American iron industry becomes apparent when glancing over the charter of the United States Steel Corporation. It confers to them practically every power conceivable in connection with manufacturing and transportation. They have the right to construct railroads and other means of transportation and to maintain and operate the same *ad libitum*.

In Germany, the prohibitive tariff imposed by the government on railway transportation of raw materials has already forced the ironmasters to approach the above subject, and in some instances has induced them to build their own electric railways, which are driven from the surplus gas energy of their works. Favourable to this practice is the growing tendency among the coal and iron interests to unite in syndicate form, which offers for the mines a constant market and to the iron works stability of fuel supply. In one case, where 34 per cent of the value of iron ores was formerly paid to the government for transportation charges, the independent railway owned by the syndicate has effected a reduction of this item to one-half; in other cases, the saving effected was 20 cents per ton of ore delivered. It was also proposed to build a high-speed electric railway

from Berlin to Vienna and to use the various iron smelting plants located along the road as sub-stations for supplying electric energy to the line; but it is found that, owing to the close concentration of industrial centers, there was in most cases an adequate consumption of the surplus power in the neighboring districts of these plants, so that not enough energy was left available for realizing the project.

It is, of course, understood that geographical, economical and governmental conditions in the United States differ greatly from those which obtain on the continent, and that territorial differences within the borders of one and the same country will often lead to different solutions in different localities. Also that where the superior facilities of transportation by boat are not available in America, low and elastic freight rates, and railways partly owned by the ironmasters, as is the case in the United States Steel Corporation, impart to the freight factor a different significance. However, the fact that in modern combined iron and steel works, this factor still determines greatly their earning capacity, and their chances of competition with other producers, and the other fact that the energy for transporting goods can be gained through an efficient transformation of the raw materials without any additional heat cost, remains invariably the same in any country or territory of the world. Since the application of gas power has proven successful in Europe, and since the gas engine industry in the United States is entering into a profitable state of standardization and balance, it is desirable that the iron industry should seriously consider to utilize, in future operations, foreign achievements, in the manner as proposed.

In conclusion, it may be said that there is nothing in the above project that requires the development of new inventions or the experimenting with untried devices. All the technical factors of the problem have been

solved individually long ago, and it is only their proper adjustment to American conditions and their judicious combination to one great end which makes this proposition an attractive subject for the engineer and economist.

The successful development of the electric locomotive and the improvement made in the generation and transmission of high-tension electric current have opened up a new era in electric railroading, and the investing public is greatly interested in the possibilities of long-distance rapid transit, connecting great centres of population or industry in competition with existing steam railroads. The greatest objection hitherto advanced by antagonists against the realization of the scheme was that where "cheap" water power was not avail-

able and fuel must be burnt at the central station to produce power for driving the generators, then the operating expenses would become entirely too high on account of the cost of coal or other fuel consumed and of the increased labor necessary for operating the plant. It is gratifying to see from the information developed above that the great iron and coal producing centers of the United States have inherent in them an enormous amount of energy which is latent at present, but which when rightly used and husbanded will yield from four to five million horse-power annually at no additional heat cost, and there can be no doubt but that some day it will be called upon to furnish its share to the novel equipment which will accomplish electric traction economically on a large scale.



REINFORCED CONCRETE IN POWER STATION CONSTRUCTION

By H. L. Knowlton

THE applications of reinforced concrete in modern engineering are so numerous and are broadening so rapidly in scope, with the increasing cost of erecting structures of wood, steel, and brick, that one scarcely knows where to begin in considering the points of usefulness of this militant material. To a large extent the characteristic features of concrete-steel, as applied to any single field, are common to its use elsewhere. It makes little difference to the designing engineer whether the foundations, beams, walls, arches and other members which he calculates and shapes are to be used in a bridge, dam, shop or power house, so far as the mathematical skill and experience involved are concerned, and in all these applications high quality of material and expert supervision of construction are vitally essential to the success of even the most thorough and skillful design. The design of reinforced-concrete structures is no task for the layman under present-day conditions; the experience and judgment of the specialist are required here more than in almost any other form of engineering construction. In some quarters the idea prevails that reinforced concrete is an unreliable material to be employed in important work, but the facts of the case are that the failures which have been sustained have in practically every instance occurred with the work of irresponsible or inexperienced designers, or from inferior material and construction.

Aside from the highly specialized technical aspects of the reinforced-concrete problem, there are a number of

considerations bearing upon the use of this material which are of no little interest to the owners of engineering properties, to operating employees of industrial systems using concrete-steel structures, to engineers specializing in other fields, and, lastly, to that portion of the general public which is interested in every real advance in applied science. The characteristics of reinforced concrete may nowhere be better studied than in its applications to the power plant. In considering the advantages of this material as applied to power-plant construction, many points arise which are equally applicable to the use of concrete-steel in warehouses, factories and other structures containing fixed or moving equipment. To get a broad view of the situation we must look into construction methods somewhat, as well as examine completed installations. No attempt will, therefore, be made in the following paragraphs to avoid reference to applications closely related to power-house work.

The contrast between modern concrete and the older form of brick power house construction is shown in the accompanying illustrations. Compare the new concrete-block power station of the Boston Suburban Electric Companies at Waltham, Mass., designed by J. G. White & Co., of New York, with the plant which it superseded.

There is no question about the relative attractiveness of appearance, of these two stations; one is a dignified, substantial addition to the surroundings, and the other is little more than an eye-sore. It has been well said that a concrete structure, whether



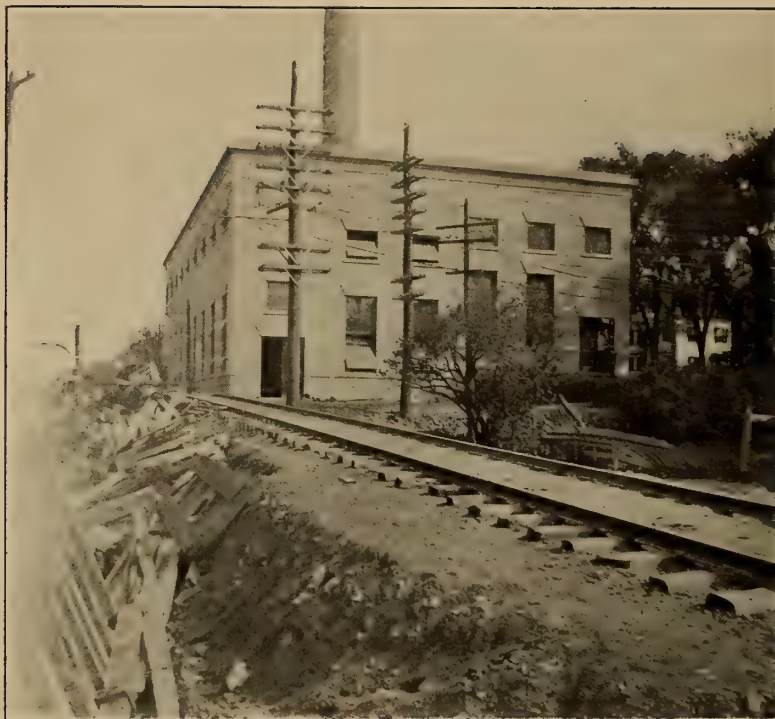
OLD STATION OF BOSTON SUBURBAN ELECTRIC CO., WALTHAM, MASS.

built of blocks or by the more common wooden-form method, soon becomes a part of the geology of the landscape, and there is no doubt that the effect of strength and permanence which well-designed structures of this kind exhibit is one of the most important architectural advantages. The chimney of the new Waltham plant is of reinforced concrete construction, and it was built with a rapidity which is typical of first-class work with this material.

Aside from its clear and attractive appearance, reinforced concrete work of good quality is probably the best of all construction materials for fire-proofing. The thermal conductivity of concrete is low, and this protects the steel reinforcement much longer than is possible in ordinary skeleton steel and tile structures, while there is no comparison between the fire-resisting qualities of concrete-steel and even the best mill construction with any ordinary reinforcement of the slabs. The strength of a floor

will be practically as great after a fire as before, and there is, of course, no danger whatever of the spreading of fires to other buildings from flying sparks, as in wooden structures. Even when badly cracked by heat, reinforced concrete stands up remarkably well under severe tests of strength. The fittings and equipment of a reinforced-concrete tower house may be destroyed, and the building will still be available for repeated use.

A steel rod properly embedded in a mass of concrete is unquestionably free from the action of rust. In his book on "Reinforced Concrete," Mr. Charles F. Marsh cites several instances of this protection, among them a remarkable case by Herr von Emperger, who discovered rods which had been imbedded in concrete under water for four hundred years coming out free from rust. Mr. E. Ransome, of New York, partly imbedded some hoop iron in concrete blocks, which were left exposed to sea air for many years. When the exposed



NEW CONCRETE POWER STATION OF BOSTON SUBURBAN ELECTRIC CO., WALTHAM, MASS.
BUILT BY J. G. WHITE & CO., OF NEW YORK

iron had rusted completely away, the blocks were cut open and the imbedded metal was found to be entirely free from rust.

Reinforced concrete is not a new material, though there are many new systems of placing the steel, designing the bars, and the like. Its durability is established beyond question, and, in fact, the chief disadvantage of this construction is its very permanence. The use of concrete began with earliest civilization. The largest dome in the world, that of the Pantheon at Rome, is a solid mass of concrete about 2000 years old. Originally, however, the material was employed only in walls and footings because of its tensile strength, and it remained for the scientific applications of steel bars and mesh in the middle of the nineteenth century to demonstrate the fitness of concrete-steel for members involving span construction.

The durability of steel, iron, and wood decreases with time in a manner not yet fully understood, and there is an almost constant expense for maintenance and painting in such structures. Brick and stone structures ordinarily require but little care in maintenance, but reinforced concrete exhibits greater lightness and economy than either masonry or brickwork, with rare exceptions a saving in first cost. In itself concrete-steel is not as light as either steel or iron for sustaining a given load. "This," says Marsh "causes its own weight to be a greater percentage of the total load than in the case of a steel or iron structure, so that the high percentage of dead to live load will prevent the use of reinforced concrete for bridges of very large span, though it is an advantage in other respects. The excess of weight is, in a great measure, compensated for in the use of reinforced concrete by

the elimination of most of the auxiliary parts necessary in an iron or steel structure. The flooring and beams of reinforced concrete act together in resisting the stresses, and there are no tie-rods, cross-girders, jack-arches, floor-plates or flooring to be supported, which in the case of a steel structure always adds considerably to the dead load. For the

power houses closely resemble inverted shells or boxes in this respect. The solidity of such structures tends to increase the life of the contained machinery through the absorption of vibration which results from it. In cases where the nature of the foundation ground is inferior concrete-steel distributes the stresses caused by unequal settlement with very little



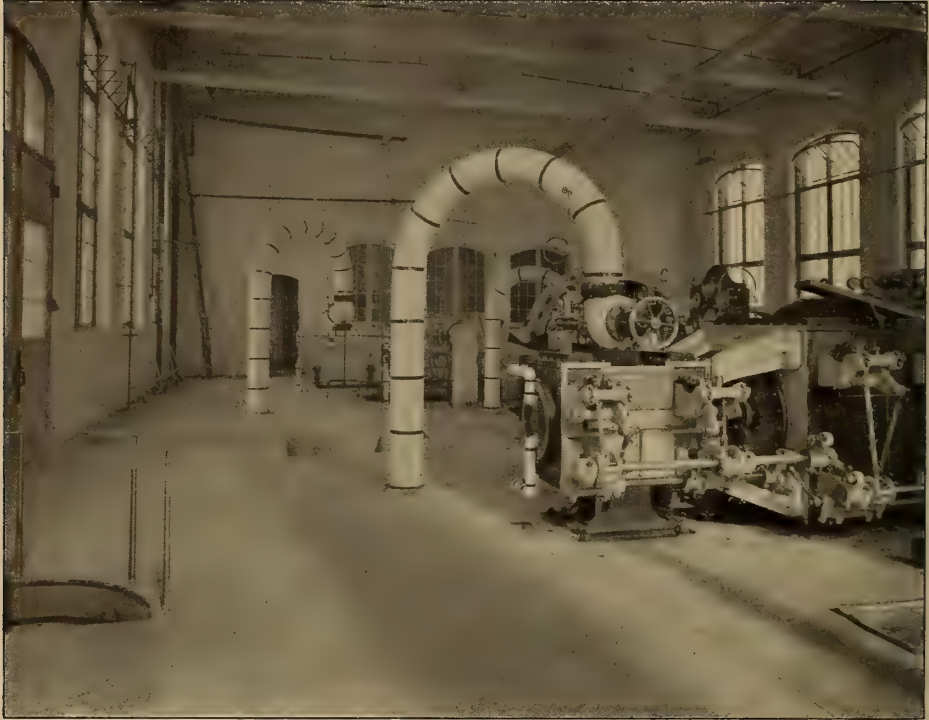
REINFORCED CONCRETE BUILDINGS. UNITED SHOE MACHINERY CO., BEVERLY, MASS.
BUILT BY THE ABERTHAW CONSTRUCTION CO., BOSTON

same strength, concrete-steel piers, abutments, arches and walls have about three to five times less volume, and, therefore, considerably less weight."

An important advantage of reinforced concrete in power house construction is its ability to resist the strains imposed by reciprocating or revolving machinery. A concrete-steel structure is, when properly put together, practically a single united whole. The walls and roofs of some

trouble. The short period and low amplitude of the vibration of a ferro-concrete structure under shock renders it long-lived, in comparison with ordinary steel and iron fabrics. Piles of concrete seldom exhibit shattering or fractures when driven into the earth by heavy impact.

An excellent example of a reinforced concrete power house is the new plant of the United Shoe Machinery Company, in Beverly, Mass. The large amount of light area is, perhaps, the



ENGINE ROOM OF THE ATLAS TACK CO., FAIRHAVEN, MASS., SHOWING FLOOR OF REINFORCED CONCRETE.
ABERTHAW CONSTRUCTION CO., BOSTON

most striking feature of this station. As compared with the previous structure, it is seen that the Beverly plant looks like a mere shell, with its narrow columns and sills. Economy of material is an important advantage of such construction. The chimney at Beverly is a typical reinforced-concrete product of the Weber Steel-Concrete Chimney Company, of Chicago. It is 141 feet 1 inch high, including foundations, and has an inside diameter of 6 feet. It was erected in sixty days, and while the concrete was only a few hours old it successfully withstood a storm with a wind velocity of 77 miles per hour. The total weight of the stack is 117 tons, of which about 7 tons is steel reinforcement, and the chimney is guaranteed to withstand a temperature of 1500 degrees F. A second chimney has been added since this photograph was taken.

An important advantage of rein-

forced-concrete chimney construction is found in the smoother interior surface which it presents, and in the reduced conduction of heat. In first cost under average conditions steel is probably the lowest, with concrete-steel next and brick last; but in point of maintenance the concrete chimney easily shows the lowest figure. A chimney 230 feet high with an inside diameter of 12 feet was built for the Portland General Electric Company, of Oregon, not long ago, the thickness of the shell being only from 5 to 7 inches, almost an absurdity at such a height and diameter, according to the old ways of thinking.

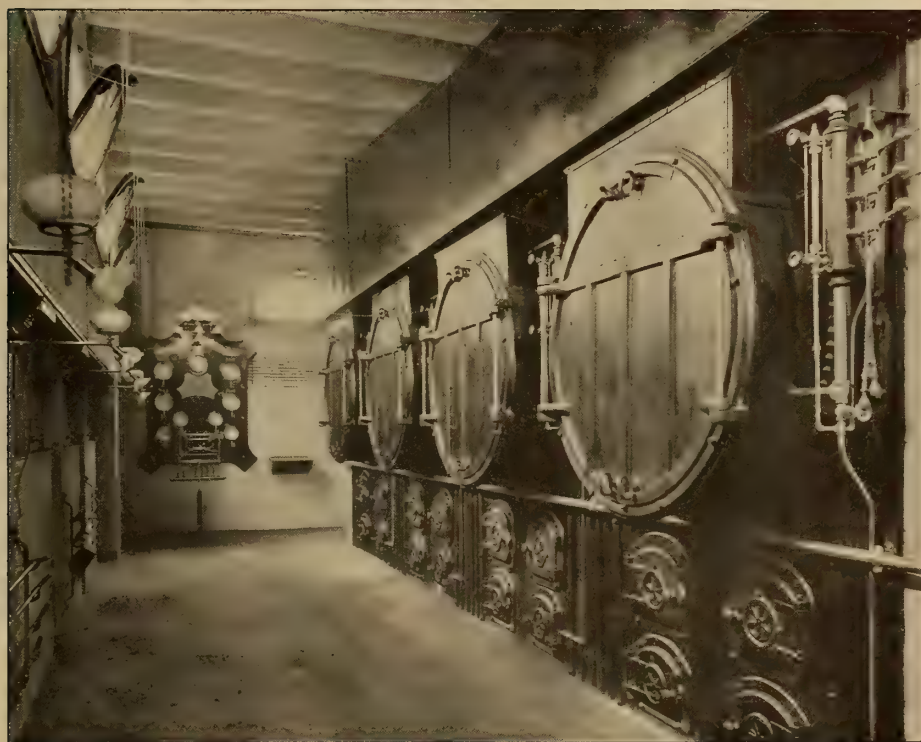
A concrete beam loaded at the middle and supported at the ends is in tension at the bottom and in compression at the top. As concrete is weak in tension, steel must be placed near the bottom of such a beam to take up this kind of strain. The beam can then fail only by the break-

ing or slipping of the bar or the crushing of the concrete at the top of the slab. The fundamental basis of all reinforced-concrete design is, therefore, the proportioning of the steel necessary to take up the tension at the bottom and the compression of the concrete in the top of the slab. Mesh reinforcement is quite as effective as bars in good construction, the strength of the reinforcement depending upon the cross-section of metal or the weight of reinforcement per square foot of surface.

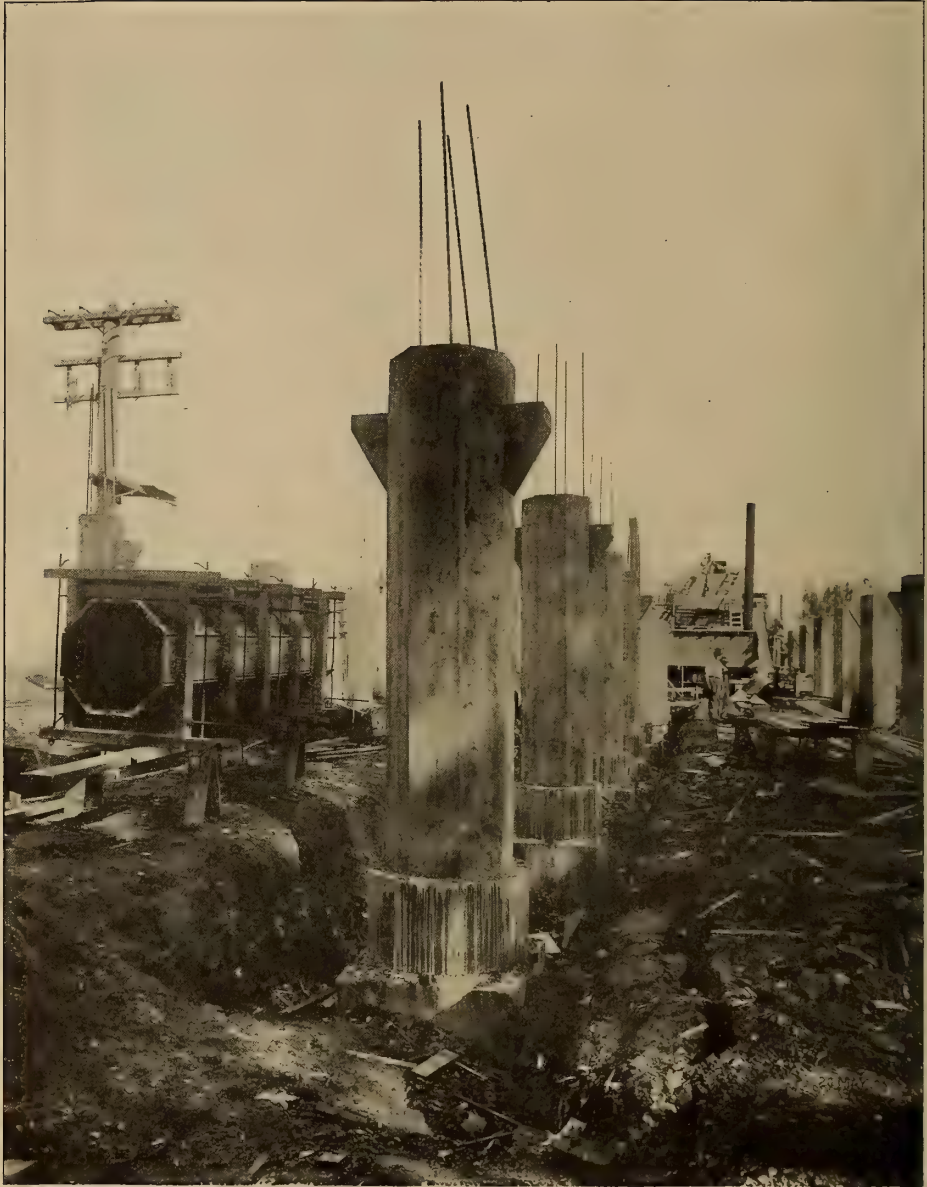
Concrete floor construction is light, quick of installation and rigid; the steel and thickness of the slab can be proportioned to carry any given load, and the slab can be made equal in strength to the steel frame. If waterproof construction is desired, the floor can be finished in granolithic form, and, as strong acids attack concrete, it is desirable to

make provision for renewing the top floor in plants where storage batteries are to be used. Reinforced concrete stairs are comparatively noiseless in use, even under conditions of heavy traffic, and the entire work of installation of a reinforced concrete structure is far less objectionable on the score of noise than the building of any steel-frame structure, with its burdensome riveting by hand or pneumatic power, or any wooden building, with its inevitable hammering.

In concrete floors without reinforcement the stresses to be encountered have made it necessary to employ the material in such massive bulk that, in a good many installations, steel and tile flooring have been thought preferable. The use of concrete steel makes it possible to employ thinner floors; the beams need be placed practically no nearer to-



BOILER ROOM OF HIGH SCHOOL AT SPRINGFIELD, MASS. WALLS AND ROOF OF REINFORCED CONCRETE.
ABERTHAW CONSTRUCTION CO., BOSTON



PILLARS OF REINFORCED CONCRETE FOR COAL POCKET AT HARTFORD, CONN.
ABERTHAW CONSTRUCTION CO., BOSTON

gether than in the case of steel construction, and, when combined with tile, the result ought to be thoroughly solid and light in weight. A reinforced concrete floor is shown in the illustration of the power plant of the Atlas Tack Company, at Fairhaven,

Mass., which was built by the Abertshaw Construction Company, of Boston. Another interesting illustration of the use of reinforced concrete by the same company is found in the view of the isolated plant of the Warren Chambers Company, Boston.

Here it was desired to use a side-walk skylight over the engine room, and reinforced concrete beams were installed to give the requisite supporting strength. Another example is seen in the boiler room built by the Aberthaw Company at the Springfield, Mass., High School. The walls and roof are of concrete-steel, the walls projecting several feet above the ground upward from the basement floor. The neatness and the

resist the water pressure from beneath when no water is flowing through the pipes. The floors and roof are of concrete-steel, as well as the beams, in the battery room.

The opinion is now generally held that a deformed bar should be used in preference to a plain bar for reinforcement. Users of plain bars claim that no artificial bond is required, but when such a bar is stretched beyond its elastic limit, the



RAYMOND CONCRETE PILES. PENNSYLVANIA R.R. POWER STATION, WESTVILLE, N. J. FOUNDATION FOR CHIMNEY IN FOREGROUND. THE SCHOFIELD CO., PHILADELPHIA, ENGINEERS

simple appearance of the construction are evident, and the liberal head room employed allows the influx of a flood of natural light during the hours of daylight.

The new plant of the Baltimore Electric Power Company illustrates the use of concrete steel in its circulating water conduits, where the reinforcement is placed on the under side of the crown to resist the weight of 30 feet of clay above, spreading out at the bottom of the conduit to

area is reduced and the bar lengthened to a permanent set, so that the grip of the concrete upon it is reduced. A twisted bar is undeniably stronger for the same weight of material. In a paper read last year before the Association of Civil Engineers of Cornell University, Mr. A. O. Cunningham emphasized the importance of using only high-grade steel, with an elastic limit approximating 50,000 pounds per square inch in reinforcement, on the ground

that it was economical, less section of metal being required than with medium steel in beams of equal strength, thus allowing a greater amount of concrete between the bars. Failure in deep, reinforced beams can be prevented by bending up the bars at their ends at an angle of 45 degrees, thus firmly uniting the upper and lower strata of the beam and preventing them from slipping on one

the mixing plant appears in the distance.

An important commercial element in such work appears in the design of the wooden forms, otherwise the cost of lumber and carpenter work becomes burdensome. In a job in which the forms are made on the ground, it is sometimes found that almost as many carpenters as labourers are required, so that an in-



RAYMOND CONCRETE PILES READY TO RECEIVE FOUNDATION PIERS.
RAYMOND CONCRETE PILE CO., CHICAGO

another. This method of laying the bars in the concrete has the added advantage of an anchorage for the reinforcement, thus preventing any slipping and pulling out of the bars.

An effective application appears in the foundation for a concrete-steel coal pocket, built by the same company at Hartford, Conn. The twisted rods are shown projecting from the tops of the octagonal columns, while at the left is seen one of the forms in which the columns are moulded;

experienced designer may overlook one of the most important elements in the cost.

A very important application of concrete in foundation work is in the use of piles made of this material. owing to the fact that wood piles decay rapidly if not permanently covered with water, it is necessary to cut wood piles off at mean low water, and the concrete floorings must start at this point and be carried up to the height of the bottom of the walls.



POWER HOUSE OF DIAMOND CRYSTAL SALT CO., ST. CLAIR, MICH., SHOWING PIERS AND BOTTOM OF 400-TON COAL BIN. KAHN SYSTEM OF REINFORCED CONCRETE

With concrete piles the tops are left just far enough below the bottom of the walls for the placing of a concrete beam thick enough to carry the weight of the building. In the construction of the new United States Naval Academy buildings at Annapolis, Md., there was a saving of \$27,000 in foundation expense over the cost of using wood piles. The concrete piles used were installed by the Raymond Concrete Pile Company, of Chicago, and were driven by the use of a hollow steel core and shell protected by a hard wood cap block, which received the hammer blows of the pile-driver, the concrete being poured into the shell and allowed to harden. Where the material penetrated is sand, quicksand, silt or soft material that will dissolve or flow up outside the pipe when water is forced through the latter, a water jet system is used in placing

the piles in position. For most foundation work it has been found that large, tapering piles are the best and most economical. By using concrete piles 18 or 20 inches in diameter at the top and 6 or 8 inches in diameter at the point, a very much less number of lineal feet of piling is required than if straight piles are used. Reinforced concrete piles are frequently used in place of solid concrete piling, though they are more expensive. Attempts to build and afterward drive the concrete pile have met with but limited success, and even though such piles are reinforced with heavy steel rods, they will not stand hard hammer blows without fracture. An example of Raymond concrete piles is shown in the foundation work of the new Pennsylvania Railroad power house at Westville, N. J., and the succeeding illustration gives a better idea of the 20-inch concrete piles at

close range. In this case the shell has been removed from the top 6 inches of the pile to give better bonding with the footing. When the core is withdrawn and the shell is filled with concrete it is possible to see that the hole is a clean and perfect one, there being no working in the dark. Every pile is monolithic.

Another form of concrete pile which has been successfully used in foundation work is the corrugated

water-jet and hammer method, only the final settling blows being driven by the hammer. The damaging impact of the hammer is taken up by a cushion fitted over the head of the pile, consisting of a sleeve filled with shock-absorbing material. Usually about two weeks are required for curing corrugated concrete piles, but they have been driven with no ill effects when less than a week old.

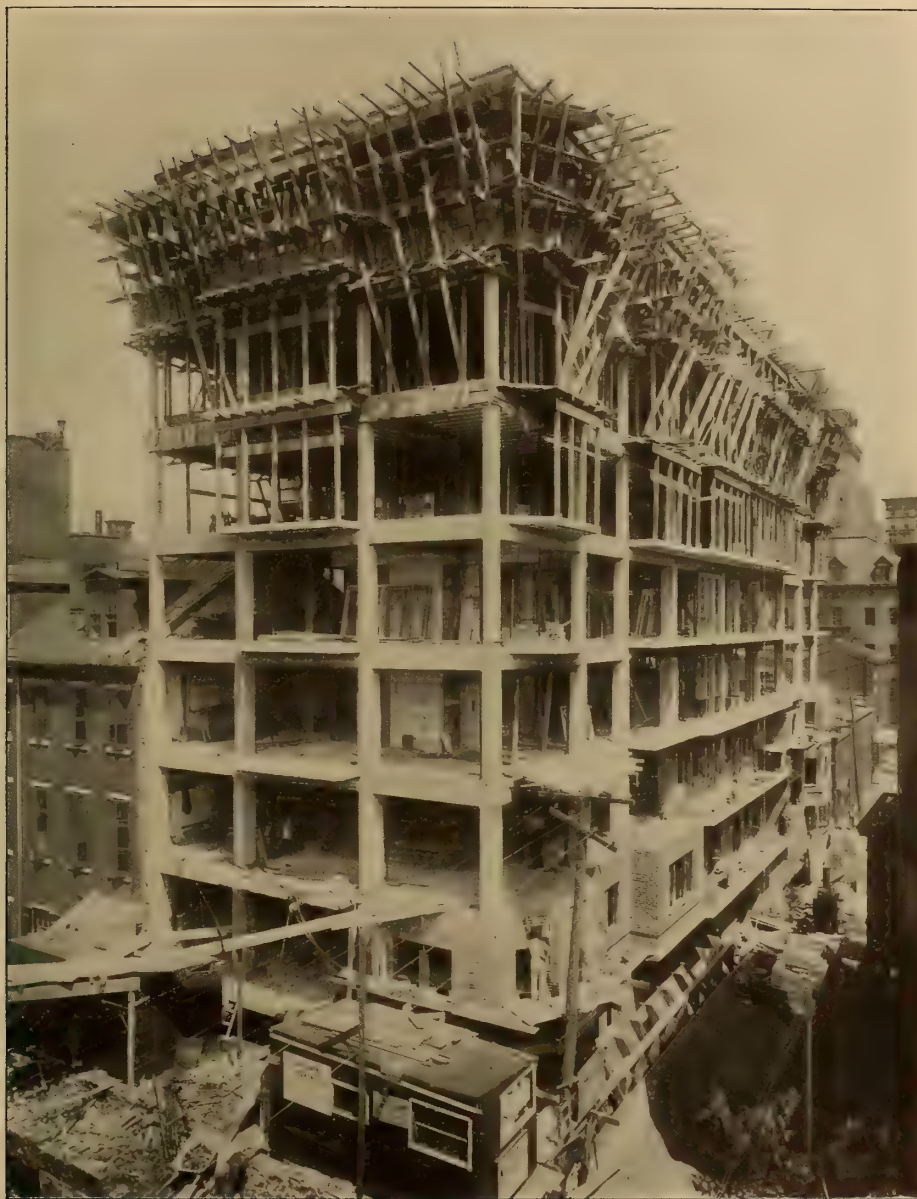
Concrete-steel caissons cost from



REINFORCED-CONCRETE BRIDGE. PHILADELPHIA RAPID TRANSIT CO. JOHN W. ALLISON CO., PHILADELPHIA

type. The increased perimeter develops a large additional skin friction for a given quantity of concrete, which means, in most cases, a gain in beating power. In a recent installation in New York, made by the Corrugated Concrete Pile Company of America, the piles for the engine and boiler settings were driven during the erection of the building proper, with no ill effects to the piles which had been driven. Corrugated piles are driven by the combination of

25 to 75 per cent. less than either wooden or steel caissons of the same size and strength, and can be built in from 10 to 50 per cent. less time. They can be built in circular or polygonal form for intake wells, piles or footings as well as in rectangular form, and as they will not float of their own buoyancy, will give double the resistance to displacement by a flood possessed by a wooden caisson. This feature is of great advantage in sinking caissons in swift streams and



REINFORCED CONCRETE APARTMENT HOUSE IN PHILADELPHIA. JOHN W. ALLISON CO., PHILADELPHIA

those subject to sudden flood. Volume for volume, a concrete caisson is two and one-half times as heavy as a wooden caisson, and in using this construction the expense and loss of time incident to using temporary weighting material in a wooden caisson will be largely eliminated. It can

be built on the site or towed to the spot, and distributes that part of the load of the structure not carried by skin friction uniformly over the entire area covered by it, while only the area covered by the chamber filling of a wooden caisson is effectively loaded, owing to the softening of the



DAM FOR JUNIATA HYDRO-ELECTRIC CO., HUNTINGTON, PA. AMBURSEN HYDRAULIC CONSTRUCTION CO., BOSTON

View of the downstream side, showing buttresses partially covered by deck and apron, also inside forms and completed deck and apron



REINFORCED-CONCRETE DAM CONSTRUCTION. AMBURSEN HYDRAULIC CONSTRUCTION CO., BOSTON

Showing the floor for receiving buttresses, also forms for buttresses, and derricks for handling material in the construction of the dam for the Juniata Hydro-Electric Co., Huntington, Pa.



REINFORCED CONCRETE DAM CONSTRUCTION. AMBURSEN HYDRAULIC CONSTRUCTION CO., BOSTON

View of the deck of dam ready to receive concrete, and showing the steel reinforcement. The concrete is delivered by gravity through chutes

submerged walls, working a saving of from 10 to 25 per cent. in the cross-sectional area of caisson required to bear a given load. The compressible roof of a wooden caisson permits unequal settlement under the weight of the masonry and superstructure. Wood softens under water, losing sometimes 50 per cent. of its strength, while concrete increases in strength with age, and will not dis-

integrate under any conditions where the use of masonry in any form is possible.

The arguments that favour the use of concrete-steel in caissons apply to a large degree in the construction of dams for hydro-electric power houses. The old wooden horse dam was a well-considered structure in its day, and it filled a large share of usefulness, but its day is passing. A

wooden dam will float if not bolted or ballasted in place; it has the least strength of all construction material, thousands of parts and joints even when new, is flexible at the sacrifice of tightness, deteriorates rapidly, costs heavily for maintenance, and has an average life of only about thirty years. A concrete-steel dam weighs two and a half times as much as an equal volume of water, has a hardness equal to trap rock, has the

of literal tightness in the structure without any offsetting disadvantages. In the construction of a dam, the loads and stresses are pretty definitely known, so that there need be but little uncertainty as to the design. If a dam is built with the sloping edges of the buttresses upstream, and with a reinforced concrete deck bearing on these, the weight of the water tends to hold the dam in place, the lines of force all fall inside the dam



CONCRETE MIXING PLANT AT THE PATAPSCO ELECTRIC MFG. CO., ILCHESTER, MD.
AMBURSEN HYDRAULIC CONSTRUCTION CO., BOSTON

highest strength of all construction material, is essentially bottle-tight, and is practically a single piece, except for expansion joints. In the single item of leakage it is not uncommon in general ballasted wooden dams to create an artificial leak in the deck in order that a constant slow movement of water may be maintained through the body of the dam in order to keep all the parts saturated and prevent rot, the leaks being accepted as the price of durability. The absolute inherent permanency of concrete-steel admits

base, and the saving of material, increased speed of building and reduced cost of construction is obvious. Such a dam can generally be built at a low cost and with greater speed than any other type of masonry dam. Among the illustrations will be seen one of a typical concrete-steel dam built by the Ambursen Hydraulic Construction Company, of Boston, for the Juniata Hydro-Electric Company, at Huntingdon, Pa. The various stages of construction are clearly shown. The buttresses are partially covered by



HANDLING FORMS BY CABLEWAY IN THE CONSTRUCTION OF DAM AT RICKETTS, PA.
AMBURSEN HYDRAULIC CONSTRUCTION CO., BOSTON

the deck and apron at the left, the inside forms are in place and ready to receive the concrete at the right-hand end, and near the right centre of the picture the deck and apron are visible. There is a steam relay plant in connection with this project, and the chimney is to be built of concrete-steel, as well as the power house.

The adoption of concrete-steel in dam construction has frequently permitted the utilization of water sites which otherwise would not have been employed without too great an investment to be justified by the income. The tightness of a concrete-steel dam may be verified by inspection, because the dam is hollow, and if leaks should occur they may be



REINFORCED CONCRETE SUBSTATION FOR PHILADELPHIA RAPID TRANSIT CO.
BUILT BY THE JOHN W. ALLISON CO., PHILADELPHIA

repaired at small expense. In passing, it is of interest to note that the Ambursen Company have recently completed a concrete-steel dam for a street railway park near Joliet, Ill., in which the hollow interior is equipped as an electrically illuminated grotto, with foot passage from one side of the stream to the other. "Many solid masonry dams have been carried out by the pressure of a great ice gorge," says Mr. W. L. Webb, in the *Journal of the Franklin Institute*, of January, 1906. "Even a wooden dam is often carried out, since a decayed plank gives a chance for the ice to bite into the surface of the upper deck. With a few planks gone, destruction follows at a cumulative rate. In the case of concrete-steel dams the deck rises by an easy incline from the very bed of the river, and the surface is smooth, uniform and very hard. It lifts the whole mass of ice easily and smoothly to the crest of the dam, and the easy incline of the apron drops it safely to the foot. If any direct ex-

pansive force of the ice exists it has no effect, as the ice is merely lifted. The time required for the construction of a dam is often a serious matter. The record of one of these dams, built without machinery, 194 feet long and 10 feet high, in only twenty-two ordinary working days, is one which will probably never again be attained except by using a similar method. In the case of a reinforced-concrete dam the stresses are very indefinite, and the engineer cannot tell exactly how much stress will be found in each detail of the design, but he is also able to design the work with any desired factor of safety. The problem of closing a dam is often a very serious one, which taxes the ingenuity of the engineer to the utmost. In a dam at Schuylerville a waterway which would ordinarily accommodate the flow of the river was left so that the water flowed through the dam for over two months. The time required for closing the openings was only forty-five minutes, a feat which could not have been



CHICAGO CUBE CONCRETE MIXER MOUNTED ON TRUCKS AND EQUIPPED WITH GASOLINE ENGINE AND CHARGING ELEVATOR

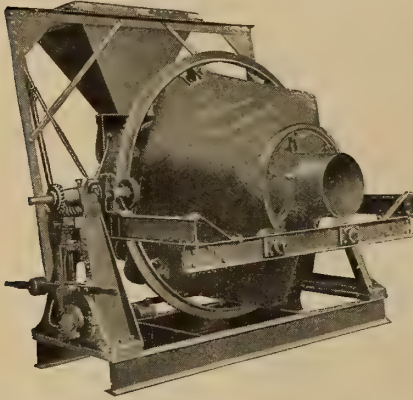
approximated with any other form of dam. The construction of the hollow dam has made it possible not only to avoid the usual expense of a gate house, which can be placed inside the dam, but will even permit the power house to be located inside the dam, and thus effect a very considerable saving on what would otherwise be the combined cost of a dam, gate house and power house. This arrangement was followed by the Ambursen Company at the Oakdale power house in Tippecanoe, Ind."

Concrete-steel foundations for machinery are coming into general use, and for moderate loads concrete columns show an economy in cost over steel columns. They occupy but little more space than a steel column fire-proofed. The reinforcement of concrete blocks is common practice in blocks much over 6 feet in length. The construction of a concrete block power house with the resulting air

spaces between the block faces makes it a much easier matter to institute additions or changes in pipe and wiring layouts than in solid masonry or solid, reinforced masonry structure. Tanks and standpipes are especially favourable subjects for concrete-steel treatment; they incur no cost for maintenance, and will last for an indefinite time. Their use in power house interiors should become more and more general.

The hardness of reinforced concrete with a large percentage of cement is a disadvantage in some ways, as it is difficult to drive nails in such structures. Holes can be made after the concrete has set if required, though the better plan is to make provision when moulding. The advantage gained by being able to mould reinforced concrete in any shape is most important, as the amount of false work on many jobs is thereby greatly reduced. Oil-switch cells, bus-bar compartments,

galleries and other auxiliary parts of power house structures are conveniently made by virtue of the plasticity of the material when fresh. Plans for the future need to be very carefully considered, however, be-



[CHICAGO CUBE CONCRETE MIXER. VIEW OF DISCHARGING SIDE

fore the final drawings are approved.

Not only are the fields of design and application of concrete-steel broad, the actual work of field construction offers the widest opportunity for the scientific organization of labour and material disposal. The labour cost is so important in concrete-steel work that the use of machine methods pays a high rate of interest on the investment. The quality of the concrete is a most important factor in the success of any structure so built, and the designer should settle this at the outset. The tendency to-day is toward "wet" concrete and away from the medium dry material which was usually specified in earlier practice. The actual handling of the material in the field is dependent upon the conditions of each job to a large extent, but good organization is the basis of all successful work. Page 498 shows the derrick method of handling material at the Juniata dam, in Huntington, previously mentioned. The floor for receiving the buttresses and forms for the buttresses themselves are shown at the left centre, the concrete mixing plant being at the right.

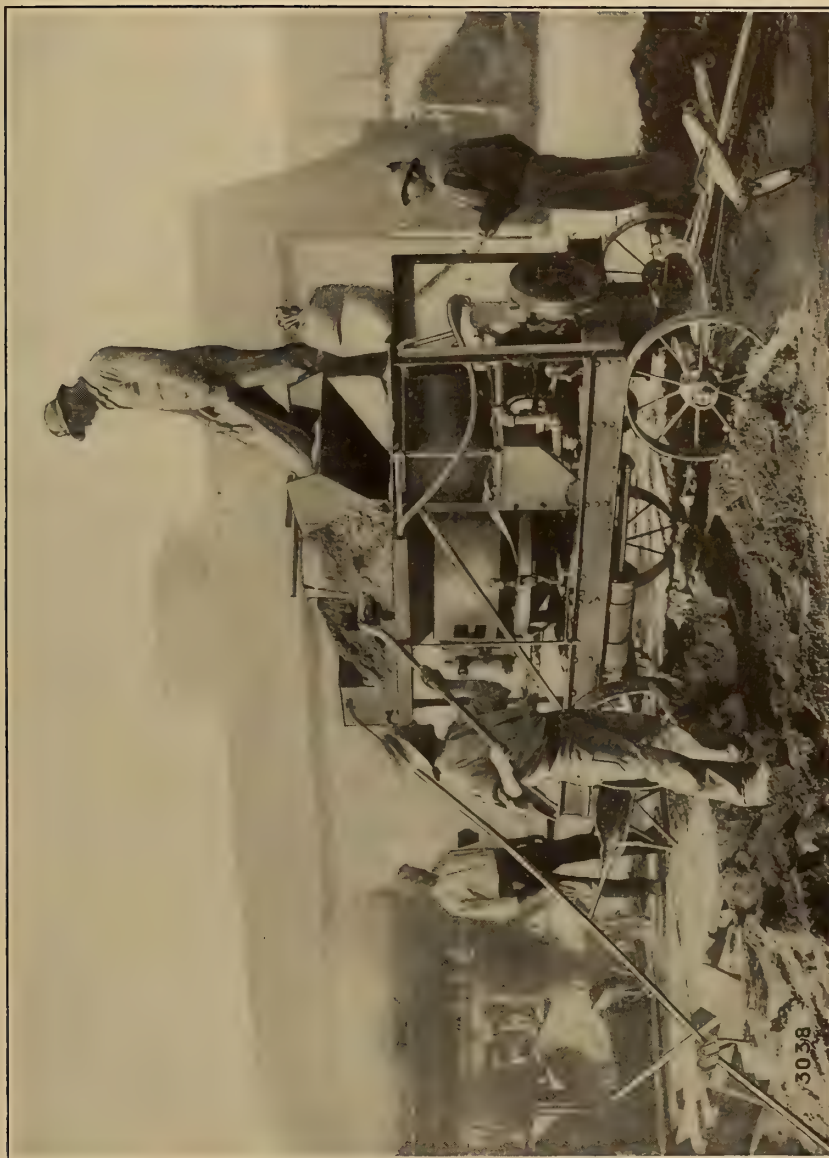
A typical mixing plant is shown at work at the new power station of the Patapsco Electric & Manufacturing Company, at Ilchester, Md. The topography of the country enables gravity distribution of materials to be easily effected. Broken stone from the crushing plant may be seen coming down one chute, while sand is run down the other. These, with the necessary cement and water, are mixed in the engine-driven mixer shown at the centre of the photograph, and the completed concrete is poured from the mixer into buckets and carried away by either a cableway or a derrick. Another method of handling concrete is shown in the construction of an Ambursen dam, in which the deck is ready to receive the concrete through the gravity chutes shown beneath the timbers. The steel reinforcing rods are clearly indicated. In the case of the Ambursen dam at Ricketts, Pa., the method of handling the sectional forms by cableway is shown. In this



CHICAGO CUBE CONCRETE MIXER ARRANGED AS A WALL MACHINE

instance the forms weigh about 900 pounds each, so the advantage of using mechanical methods is obvious.

No class of concrete work requires such care in mixing as concrete for reinforced practice, for in case of a slight imperfection in the mixture of concrete for a floor, for example, failure is imminent on account of the



THE TRUMP PORTABLE CONCRETE MEASURING AND MIXING MACHINE.
THE LINK-BELT ENGINEERING COMPANY, PHILADELPHIA

extreme thinness of the material. Mixers are now on the market which measure out the proper quantities of sand, cement and stone, apply the necessary water, and produce by thorough agitation fresh concrete of reliable quality for any desired service. These machines are accurate in their proportioning of ingredients, adjustable for different portions, "fool-proof," positive in operation, rugged in construction and automatic in performance, besides being portable and cheaper in operation than hand mixing. To discuss the characteristics of modern concrete handling machinery in detail is beyond the scope of this article, but one or two representative appliances may be mentioned to show the degree to which manual labour may be superseded.

Among modern machines may be mentioned the "Trump" concrete mixing machine, made by the Link Belt Engineering Company, of Philadelphia. This machine will supply concrete at the rate of 7 cubic yards per hour. The source of power is optional, and is permanently mounted on the frame. It may be either gasoline, electric or steam. The measuring device consists of a horizontal revolving table, on which rests the material to be measured, and a stationary knife set just above the table and pivoted on a vertical shaft outside the circumference. The knife can be adjusted to extend the proper distance into the material, and peels off at each revolution of the table a certain amount, which falls into a chute past the moistening devices. Thence the materials fall into a short trough, where the mixing is completed by hardened steel paddles revolving on a shaft, and the concrete falls from this trough ready to lay. The use of a mixer often obviates the need of an inspector at the work.

Another modern mixer is the Chicago improved cube type of the

Municipal Engineering & Contracting Company, of that city. This device is self-cleaning, it has no internal mechanism, the machinery is simple, and it will mix thirty batches of concrete per hour. It has no tendency to become clogged, and the mixing chamber is a cube which contains no obstructions. It is equipped with automatic charging and discharging devices, and requires no other manual labour than an engineer to handle the necessary levers. Speed of mixing is one of its most salient points, and charging can be done within 12 inches of the ground.

The Ransome mixer is a well-known standard product in which the body revolves continuously, even while the concrete is being discharged. The concrete is thoroughly mixed during the revolution of the drum by steel scoops; the drum makes 15 revolutions per minute, and at every revolution each of the steel scoops flows fifteen times through the material. Nothing is left to chance. When it is desired to empty the mixture of all or part of the concrete batch, a simple pull of the lever lowers the discharge chute to the proper point and delivery is effected. The discharging mechanism is the most striking feature of this mixer.

Lack of space forbids further discussion of the labour-saving devices by which reinforced-concrete construction may be economically carried out. In the new Seattle concrete-steel power house of the Columbia Improvement Company, Mr. Frank B. Gilbreth, of New York and Boston, employed a number of characteristic labour-saving methods, peculiar to his organization. At Sprague's Falls, Me., a town which this contractor built complete in eight months, a concrete dam 2000 feet long was one of the most prominent engineering features handled by perfected organization and machinery.

THE ELECTRICAL POWER SUPPLY OF LONDON

By C. S. Vesey Brown, M. Inst. C. E., M. I. E. E.

HE last fifteen or twenty years has witnessed a gradual concentration of all the forces of nature "directed to the service of mankind," which are required for large communities.

Water, gas, drainage systems and transportation facilities are among the problems which have had to be solved as the population and area of the large cities of the world increased, and it is only necessary to point to the engineering features involved in providing these facilities for towns like New York, Paris, Berlin, Manchester, Liverpool, Glasgow, etc., etc., to realize the truth of the above statement.

London is peculiarly situated in this respect. The first great engineering work of concentration tackled, on account of the increase of population, was that of drainage, under the superintendence of the late Sir Joseph Bazalgette. The principles which guided him in laying out the main arteries for the reception and transmission of the drainage of London might with advantage be followed in considering the problem of supplying London with a cheap supply of electrical power.

The examples of the different metropolitan gas companies in concentrating the manufacture of gas, the recent amalgamation of the water companies and the control of the surface and the major portion of the underground transportation by the London County Council and the Underground Electric Railways Com-

pany, of London, all go to prove the necessity of some central authority for the supply of electricity throughout London and the surrounding districts.

The partition of the United Kingdom into suitable areas for the establishment of electric power companies is now practically complete. Such power stations as are equipped have been generally designed to supply at the cheapest possible rate for manufacturing purposes and to make as much use of the advantages of concentration that it is possible to obtain. Moreover, the establishment of these power stations will enable the smaller boroughs and urban district Councils around the industrial districts so provided for to take advantage of the cheapness of the power, in order to distribute electrical energy, principally for lighting, and thus bring within the reach of every one what was at one time considered a luxury, but is now recognized to be a necessity.

There are several factors which have militated against the erection of central power stations on the fringe of London to transmit by high pressure and convert to low pressure at sub-stations in the crowded parts of the metropolis. The principal of these difficulties are:—

(1) The purchasing power in 1931 of the local authorities under the Electric Lighting Act of 1888. (The term of all provisional orders granted to limited companies for areas in the administrative County of London expires in 1930; that is to say, under the terms of the Electric Lighting Act of 1888 the several undertakings may be taken over by the respective local authorities on paying the "then

value" of the plant, etc., without any allowance for good-will.)

(2) The disturbance in the west central parts of London by the "improvement" operations of the London County Council.

(3) The difficulty of obtaining suitable sites for generating stations at a reasonable price which are well equipped with coaling facilities and condensing water.

(4) The heavy cost of laying transmission cables through the principal streets, in order to connect the outside stations with the local sub or transforming stations.

The first of these points is undoubtedly responsible for much of the opposition to the proposals made in the 1905 session of Parliament for the establishment of the large electric power stations suggested by the promoters of the Administrative County of London and district electric power bill.

Existing undertakers had expended large sums of money in building and equipping works which might become inoperative owing to the use of the administrative company's "power," and the period of twenty-five years left to 1930 would not leave enough time to provide reasonable depreciation on the plant put out of use. Whatever may have been the reason, it is certain that the effect of the proposals contained in the bill would have been advantageous to the London power user, and did ultimately help him, as the charges for "electric power" were at once reduced by a majority of the suppliers to 1d. per unit, and even less in some cases, with a corresponding increase in the consumption of electricity for power.

At this point it may be interesting to give a brief historical review of the establishment of electricity supply as far as it concerns London proper. The supply to the surrounding districts has grown up later, and, with the experience of the earlier stations as a guide, many of the difficulties which confronted the pioneers

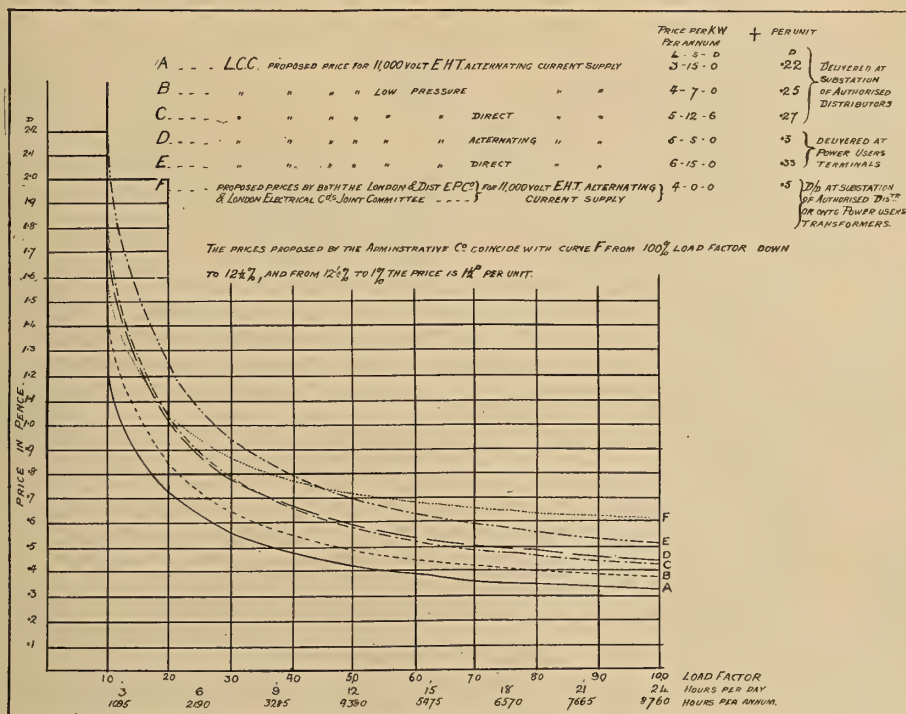
have been avoided with care and success.

London has long been the happy hunting-ground of the electrical promoter; in the early eighties the Brush and Edison stations were started, and have long since disappeared into the limbo of the forgotten past. After the 1888 Electric Lighting Act was passed, and as a result of a Board of Trade inquiry under the late Sir Francis Marindin, the areas immediately surrounding the Cities of London and Westminster, and generally within a radius of four miles from Charing Cross, were carefully allotted to eight companies (two in each area, one to supply light and the other to supply power, though, of course, either company could supply both). The reason for this arrangement was, that at the time of the inquiry, the system of supply most favoured by engineers for lighting was the single-phase, alternating-current system, generating at any pressure from 1000 to 10,000 volts, and transforming to 100-volt supply at the lamp terminals, and this was not then adaptable for the use of power, whereas the continuous current supply on the three-wire system with 200 volts on the outer conductors, and also 100 volts at the lamp terminals, was quite understood, and was, in fact, used in a number of small works to drive motors on cranes, lathes, etc.

It was recognized that a certain amount of electric power would be required, and for this reason the Board of Trade allotted two companies to each area,—one to supply alternating current and the other to supply continuous current.

The companies started work practically simultaneously, though the London Electric, Kensington & Knightsbridge and the Metropolitan Companies had the start of the others, on account of the non-statutory stations owned by them at the Grosvenor Gallery, Kensington Court and Rathbone Place, all supplying by overhead wires.

Outside the area supplied by these



ELECTRICAL SUPPLY FOR LONDON
CURVES SHOWING DIFFERENT PRICES FOR VARYING LOAD FACTORS

and other companies, the local authorities of St. Pancras, Hampstead, Islington, etc., decided to establish works and supply electricity within the boundaries of their respective "vestries" as they were then constituted.

The first to do so was St. Pancras in 1891, and from these small beginnings the area of electrical supply and the number of authorized undertakers has grown in London and the surrounding districts, so that at the present time there are no fewer than seventy generating stations in operation, without taking into account the numerous tramway and railway power stations. The majority are situated within their own "area of supply," and a few are without, from which the energy is transmitted at high pressure to the "area of supply" from favourably situated sites for cheap fuel and water for condensation. These latter stations are

all erected under special Acts of Parliament.

The question of supplying a large portion of London from one central station was originally proposed by Mr. S. Z. de Ferranti and the financiers associated with him in the organization of the London Electric Supply Corporation, Ltd. His scheme of supply by extra high pressure single-phase current from Deptford paved the way to what is now recognized as the right thing to be done in order to take advantage of sea-borne coal and abundance of condensation water.

The Deptford power station and its general system of supply (as carried out by these gentlemen) have passed through a series of financial and engineering vicissitudes which would have shaken the faith and endurance of a good many people, but its latest reports show that the advantages of the riverside site and the arrange-

ment of supplying from that position are at last telling in its favour.

It was some time before the example was imitated, and it was not until ten years later, in 1898, that the first move was made by other companies to erect generating stations on the outskirts of London to supply the increased public demand and to relieve the pressure of space in the overcrowded stations in the centre of the West End and City of London.

A radical change came over the ideas of the electrical engineer with the advent of large steam turbines using superheated steam, and the reliance to be placed in the higher pressures used in electrical generating machinery and cables. With the experience deduced from the knowledge of these facts and the results of the operations of the Newcastle-upon-Tyne Electric Supply Company at their power station on the river Tyne, it is not surprising that when the Administrative County of London and District Electric Power Company promoted a bill in 1905 for the erection of equipment of three large power stations, containing plant capable of supplying "in bulk," and, in competition with existing undertakers, to supply electric power to manufacturers only, that a storm of indignation and skeptical criticism should burst over the heads of the promoters.

The public and the manufacturer alike, however, recognized that the time had arrived when the problem of supplying London with electrical power on the cheapest and most efficient lines must be faced and solved. Manufacturers were gradually moving their works to districts where fuel and land were cheaper, labour less expensive and the heavy rates exacted in London were unknown.

Dear land, heavy rates, high cost of labour, were all quoted as being the reason for the difference in the rates for electric power in London as against Tyneside, and, after a long and strenuous contest before Par-

liamentary committees (resembling in appearance the array of counsel and witnesses in the palmy days of the rush for railway concessions), the area of London and the surrounding country was parcelled out to three companies authorized to supply electric power "in bulk."

The Metropolitan and North Metropolitan Companies (two of the companies in question) were fortunate in not encountering further opposition in the second House of Parliament, and their bills were passed into law, the areas of supply being shown in plan No. 2. The Administrative Company was less fortunate, for though its scheme was favourably reported on by the committees and the promoters had agreed terms with every one of its opponents, it was lost by a "short head" on the day of the prorogation of Parliament.

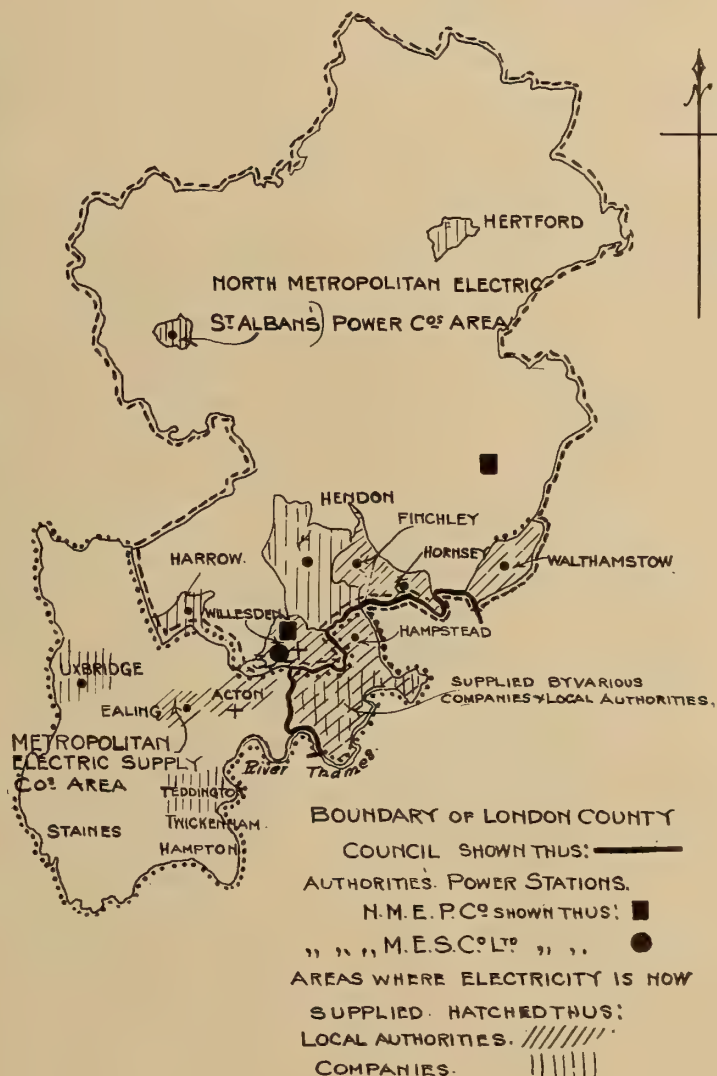
Thus it will be seen that the northern and north-western part of London are provided for as regards cheap power, and the southern and eastern districts were left to be decided either this year or in some future session of Parliament.

The London County Council have made several efforts since 1902 to obtain statutory powers for the purpose of consolidating the electrical supply in London, and this year sees a further attempt in this direction.

The year 1905 saw the real first suggestion of a comprehensive scheme by the Administrative County of London & District Electric Power Company. In 1906 nine proposals were suggested by different promoters, but the government decided to narrow the margin of inquiry down to the question of whether or not the London County Council should be the statutory authority. The County Council's proposition was considered and finally rejected, with various recommendations to that authority as to what principles should be observed in framing another bill in 1907.

The plan No. 3 shows the area proposed by the London County Council

A. NORTH METROPOLITAN ELECTRIC POWER CO.,
 SHOWN THUS:-----
 B. METROPOLITAN ELECTRIC SUPPLY CO. LTD.,
 SHOWN THUS:.....



in 1907, which is practically the same as that proposed by the Administrative Company in 1905 and 1906.

Four different proposals are promoted in the present session of Parliament, as follows:—

(1) The London County Council, with two power stations.

(2) The London & District Electric Power Company, with two power stations.

(3) The London Electrical Companies Joint Committee.

(4) The Administrative County of London & District Company.

The first and the last are old opponents, and in the latter case the bill simply assumes that the County Council will obtain the powers sought and the promoters ask that they should be empowered to lease and work the powers granted to the County Council.

The County Council's proposals are, shortly, as follows:—

(1) Four years after passing the Act notice may be given to any Borough Council within the Council's area operating electric power stations or owning a provisional order that the Council wish to acquire same, and a transfer is to take place within one year from the notice to acquire, the price being the capital value of the undertaking, as represented in that Borough Council's accounts; the County Council then assume all responsibility for payment of interest and sinking fund on the capital, etc. The Borough Councils of Marylebone and Woolwich are exempted from this clause entirely.

(2) The Borough Council may not incur further capital expenditure without the County Council's consent from the date of passing of the Act.

(3) The County Council may acquire by agreement such other undertakings as it may wish to belonging either to companies within the County Council area or to others outside the County Council area, but within the "area of supply" authorized by the Act.

(4) The County Council may sup-

ply any power user direct in any area with the consent of the Board of Trade.

(5) The County Council proposes to usurp the power of the various Borough Councils to purchase the undertakings in 1930 now owned by the operating companies and take the business into its own hands.

(6) A clause, similar to that inserted in the "Bermondsey" provisional order, is to become operative after five years. The clause imposes an obligation on the Council to alter its prices if the result of any one year's trading shows a loss; i. e., if a loss is incurred the prices of supply are to be raised so that no relief is given to the undertaking from the rates.

There are other clauses relating to finance, such as period for borrowing money, etc.

The capital asked for by the bill is £4,500,000.

The maximum prices authorized to be charged are to be as follows:—

PROPOSED LONDON COUNTY COUNCIL

ELECTRIC POWER CHARGES

To Authorized Distributors:

Extra high-tension alternating current, £3 15s. per annum per KW. of maximum power, plus .22d. per unit.

Transformed supply, alternating current, £4 7s. per annum per KW., and .25d. per unit.

Direct current supply, £5 12s. 6d. per annum per KW., and .27d. per unit.

To Ordinary Consumers:

Transformed alternating current supply, £5 5s. per annum per KW., and .3d. per unit.

Direct current supply, £6 15s. per annum per KW., and .33d. per unit.

The bill promoted by the London & District Electric Power Company is nearly on all fours as regards area and other particulars with that proposed in 1905 and 1906 by the Administrative Company.

The maximum prices of supply are to be either 2d. per unit or alternatively £4 per annum per maxi-

imum KW. demanded and $\frac{1}{2}$ d. per unit. No distinction as to class of consumer is made.

The bill proposed by the joint companies contains the following clauses, amongst others—

(1) A joint committee of fourteen companies, to regulate the operation of each company and any station supplying the companies "in bulk."

(2) The putting back of the date at which all the company undertakings may be acquired by the local authority under the 1888 Act from 1930 to 1949, with three years' notice instead of one.

(3) The terms of purchase at the latter date not to be those of the 1888 Act, but to be by agreement, or, failing agreement, to be settled under the Lands Clauses Act. The proposal only applies to the stations and works of the companies, the remainder of the undertakings to be purchased under the provisions of the 1888 Act.

The maximum prices of supply to be at the rate of £4 per annum per maximum KW. demanded plus $\frac{1}{2}$ d. per unit.

The above is a recital of the principal clauses in the respective bills for the session of 1907.

One point which is clearly brought out in the proposals by the different promoters is the uniformity with

which each has considered the possible "consumer."

The prices asked to be authorized are such as should tempt the majority of power users to contemplate seriously the use of electricity in place of steam or gas.

The user at low load factor will be able to get current at from 1d. to 2d. per unit, and when the load factor reaches 40 per cent. or over the charges compare very favourably with what is paid anywhere else in Great Britain.

On the whole, one may look forward to the manufacturer receiving every benefit that is possible whoever may be the supplier of electrical energy.

The table below gives the comparison of what is proposed to be charged for different load factors.

The curve represented in Fig. 1 shows the relation between the proposals of the different companies and the County Council.

It is not stated whether the prices quoted are to be subject to a standard price of coal, but if this is not so it is obvious that the income of any of the promoters will be subject to the fluctuations in the price of coal, and what is good for coal at 9s. to 10s. per ton may be altogether upset if the price goes up.

On the other hand, if coal goes

TABLE A.

LOAD FACTOR.	L. C. C. Extra High Tension Alternating Current Supply.	L. C. C. Low Pressure Alternating Current Supply.	L. C. C. Low Pressure Direct Current Supply.	L. C. C. Low Pressure Alternating Current Supply.	L. C. C. Low Pressure Direct Current Supply.	Proposed prices by London & Dist. El. P. Co. & London Electrical Co's Joint Committee, E.H.T. Alternating Current Supply.	Administrative Co's Price in 1906.
	AUTHORIZED DISTRIBUTORS.			ORDINARY CONSUMERS.		AUTHORIZED DISTRIBUTORS AND ORDINARY CONSUMERS.	
%	Per Unit.	Per Unit.	Per Unit.	Per Unit.	Per Unit.	Per Unit.	Per Unit.
10	1.249D	1.441D	1.811D	1.738D	2.179D	1.695D	1.500D
20	.733	.845	1.04	1.019	1.255	1.047	1.047
30	.562	.647	.784	.779	.946	.865	.865
40	.477	.548	.655	.659	.792	.774	.774
50	.425	.488	.578	.587	.699	.72	.72
60	.391	.449	.527	.54	.638	.682	.682
70	.366	.420	.49	.505	.594	.656	.656
80	.348	.399	.463	.479	.561	.637	.637
90	.334	.382	.441	.459	.535	.622	.622
100	.322	.369	.424	.443	.515	.609	.609

down the power user should have the benefit of the reduction.

If the supply is eventually handed over to a company, Parliament will fix a definite ratio between the average price obtained and the dividend, and further provision should be made to protect both parties as regards the fluctuations of coal prices.

Looking further ahead and considering the question on its merits, the following observations on the general policy may help in the solution as to what is best:—

At first sight, and in accordance with the growing tendency to place such matters as these in the hands of a popularly elected assembly, one would say that the London County Council is the proper authority to whom the supply "in bulk" of electrical energy for London should be entrusted.

English ideas as to local government are "parochial" to the last degree, and it is a very difficult matter to eradicate the principles which we have governed the allotment to each local authority the right only to supply or regulate such public requirements as gas, water and electricity, and to confine such supply or regulation of the "parochial" boundaries formed in past ages for an entirely different purpose, when County, Town and District Councils, as now constituted, were unheard of.

The principles of self-government on these lines for sanitation and drainage, watching, street lighting, and other such matters which are properly applicable to each particular community is a good one, but it is open to question as to whether it is not carried too far when it is necessary to provide the public with gas, water and electricity. This is no place to argue for or against municipal trading; but, at the same time and without prejudice, a protest can be properly entered against the confinement of such businesses when it is vital to the interests of every one that they should be so designed as to be capable of supplying at a cheaper

rate when several districts are served from one centre than for each particular "parish" to operate its own little gas, water or electricity works.

The "greatest good to the greatest number" is a motto which might be well applied when consideration of electricity supply is in question, and one is inclined to wish sometimes that the decision, as to the merits or otherwise, of some particular scheme could be left in the hands of a Napoleon or a Czar.

The anomalous positions in which many of the electric supply undertakings of the present day find themselves would have been avoided if Parliament had carried out the principle enunciated by the Board of Trade in 1888, and held inquiries as to the "necessities" of each district, instead of granting provisional orders on the problematical requirements as set forth by promoters, be they local authorities or limited companies.

One cannot complain that the County Council have been backward in asking for a wide enough "area of supply." The plan accompanying this article shows clearly how much this area extends beyond the legitimate boundary of the County Council. The proposals involve invasion of territory already allocated to "power companies" besides the numerous "authorized distributors," as regards the "power areas" already allocated.

There are sure to be difficulties in raising the capital required for either of the "power supply" competitors unless there are protective clauses added to the bill before it becomes law, especially as the two companies are already at work and are laying the foundation of a business on the good faith that the tenure is a good one and that the capital involved will not be disturbed within a reasonable period sufficient to allow of proper depreciation and sinking fund to redeem it.

The proposals put forward in the bill do not merely cover supply "in bulk," but all the distribution required when the whole of the un-

dertakings are taken over. The capital of £4,500,000 barely touches the question when it is known that the sum of £19,000,000 has already been expended by companies and local authorities.

Unless Parliament restricts the County Council to such "retail prices" as will protect the consumer, there is no doubt that difficulties will arise in different parts of the area of supply in the event that the "Bermondsey" clause becomes operative.

What, for instance, would the East-Enders say if his price is raised in order to clear up a deficit which is well known is caused by reduction in the use of electricity in, say, Battersea or Hampstead; or, again, if some of the areas outside London proper are particularly remunerative, such, for instance, as Croydon or Ealing, would the consumer in these places be satisfied if he knew that his profits were going to relieve the rates in, say, Poplar or West Ham?

Then, again, why should Woolwich and Marylebone be left out in the cold when their neighbours are being supplied at lower rates than those at which they can produce, or what will be the feelings of these two places when the County Council has surrounded them with cheaper power than they can produce and has induced all the good customers to migrate outside the boundaries and boroughs who cannot supply as cheaply as the County Council?

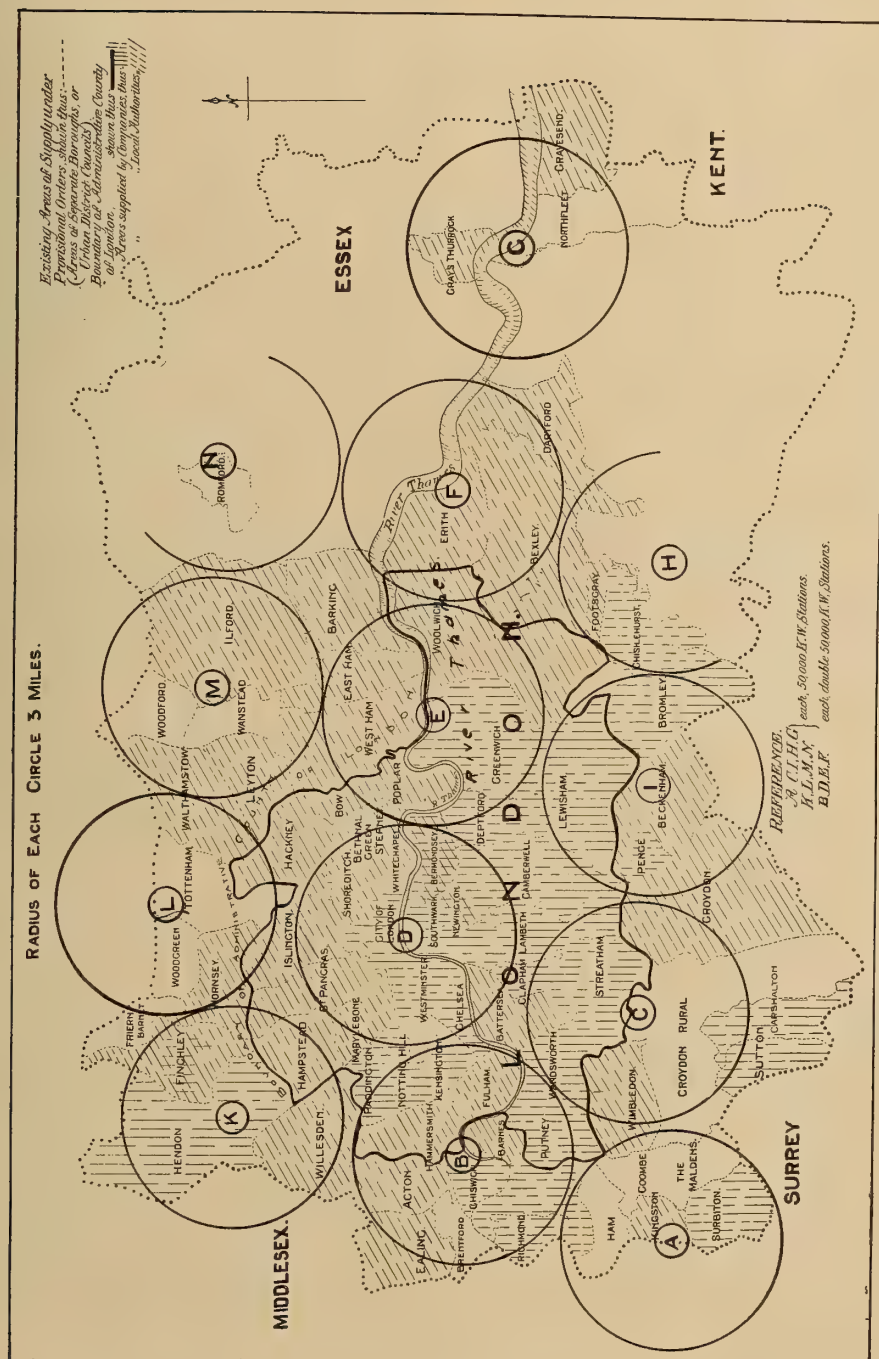
The proposal to supply possible customers of the different "authorized undertakers" opens up a number of extraordinary positions. The London County Council is the "financial house" to whom all Borough Councils within London proper are obliged to apply for money and the leave to spend it, after clearly stating how the money is to be expended. Assume that the Borough Council are in competition with the City Council for the supply of power to a power user in its area, and that the sanction of the

London County Council is asked to authorize by the Borough Council to spend the necessary capital to supply the consumer, and, as is quite possible, the London County Council refuse their sanction and proceed to supply the consumer from their own works, with the possible result that there is a loss on the transaction which involves a rate to cover the deficit, is it equitable that the rate so levied should be borne by all the boroughs who have no part, or, say, in the transaction and especially by the particular borough invaded, whose Council might reasonably argue that if they had supplied the energy there would have been a profit on the transaction?

The proposals of the County Council are hedged about with possible anomalies of this nature, and none of them are more difficult to settle than the following proposition:—

Suppose the County Council make a profit or a loss, after meeting all charges and paying interest and sinking fund on the capital outlay, in supplying power to any of the outside areas, and do not supply anyone at all (or only a very small proportion of the outside) inside the County of London, to whom does the profit legitimately belong? Or on whom should the loss fall? The London County ratepayers or the ratepayers in the districts supplied in bulk? If the latter, how is the rate to be levied, and who is to be authorized to collect it?

It is admitted that there is a field for further supply of power (evidence for the Administrative County showed that there was about 450,000 horse-power to tackle, and that the main idea of the promoters of this bill for bulk supply was to tap this undeveloped area); but, on the other hand, there is no doubt about the necessity for improvement in the existing arrangement of London's generating stations, and if it is possible to remove one-half of them and transfer the current now generated to larger stations, it will be



seen that there would be already created a load of at least 100,000 kilowatts to be dealt with, without counting the additional plant wanted when "cheap power" is available.

England in general, and London in particular, are dependent entirely on the supply of cheap fuel from the coal fields of the North-East Coast, the Midlands and South Wales.

There is no other natural source of power available, such as water-power, oil, natural or even blast furnace gas.

Under the circumstances it is vital to any scheme for the supply of power that every advantage should be taken of the natural position which the river Thames affords for:—

1) The conveyance of the fuel direct from the producing colliery to the boilers in the generating station.

(2) The extraction of all the available heat in the steam generated by the fuel, by using the river water for condensing purposes.

Suggestions have been made as to the generation of power in the Midland or South Wales coal fields by means of gas engines supplied from the products of the distillation of coal at the "pit's mouth."

While not wishing in any way to throw cold water on the enthusiast who looks forward to the time when electricity will be delivered in large cities at a fraction of the present cost, one cannot help pointing out that there are other considerations involved in such proportions than those of cost.

It is idle to suggest an overhead line of wires from Derbyshire to London to convey 250,000 kilowatts at, say, 60,000 volts; no such line has yet been built or projected.

The greatest capacity of any one overhead line in use in North America is 20,000 kilowatts, and to suggest stringing ten or a dozen of such lines to serve London is chimerical to the last degree.

It is undoubtedly cheaper to carry coal to London than to distill it, use the gas for generating, and trans-

mitting the energy along overhead wires costing anything up to £110 per ton for copper.

The question of the number of stations is not an easy one to solve. The suggestion of three stations does not really cover the ground properly, as there are the areas allotted to two other companies besides the power stations erected to serve several railways and tramways.

It is difficult to decide how the supply of any commodity in daily use in London and its surroundings is to be produced. Water is delivered from at least nine different sources, with many sub-divisions for distribution. Gas is under the control of eleven different companies, with as many more manufacturing centres; hence, it is difficult to say off-hand that London's electrical demand can be properly supplied for even eleven electric power stations.

In order to show to what dimensions the electric supply of London has grown, the following table is interesting:—

TABLE B.

Number of generating stations now in operation.....	70
Number of substations supplied in bulk.....	45
Number of local authorities supplying electricity.....	41
Number of companies supplying electricity.....	20
Units supplied:	
Companies, year ending Dec. 31, 1905.....	129,000,000
Local authorities, year ending March 31, 1906.....	62,000,000
Total capacity of plant installed at the end of 1905:	
Companies.....	132,000 kw.
Local authorities.....	70,000 kw.
Maximum demand during 1905:	
Companies.....	76,000 kw.
Local authorities.....	34,000 kw.
Capital expenditure to Dec., 1905 and March, 1906:	
Companies.....	£13,000,000
Local authorities.....	£6,000,000

The figures are exclusive of the railway or tramway electric power stations, and refer solely to the supply from power stations established under provisional order or special Act of Parliament (compiled from data in "Garcke's Manual of Electrical Undertakings").

The largest power station at Niagara or in Canada will not contain more than 100,000 kilowatts un-

der one roof (though there is one being built on the Canadian side to hold 150,000 kilowatts), and assuming that it is possible to concentrate that amount of plant when driven by steam turbines on to one site (leaving the roof out of the question), there still remains the greater question of the supply of power for railway traction, which is at present only just touched, and which will, at some future date, involve the operation of many thousands of horse-power of electrical generating plant.

Looking at the question from a point of view which is not prejudiced by interest in any particular scheme, a solution of the problem may be found in much the same manner as that adopted towards the first promoters of provisional orders.

There is a certain portion of London which may be said to be "settled" as regards the number of houses, arrangements of streets, etc. Let these parts of London be allotted to one or more power stations and restrict their operation to those areas subject to provision for inter-connection with other power stations situated further out on the fringe of London, as it is to-day; and, as the area widens with the growth of this modern Babylon, so let other power stations, similarly restricted to a definite area and policy, be erected. Let the original stations be erected on the banks of the Thames, and the limit of each be 50,000 to 75,000 kilowatts, with a three-mile radius, and in the case of two or three of the congested areas two stations of similar capacity could be erected on each side of the river,—such a scheme is outlined on plan No. 4.

Parliament must decide on the policy of allowing private or municipal control of such works; but, whatever scheme or policy is decided on, let it be one which is capable of treatment in a broad-minded spirit,

untrammelled by parochial considerations.

It must not be forgotten that the foundation of British supremacy in the markets of the world of manufactured goods is based on cheap fuel and efficient labour. To maintain such a position against competition by "bounty fed" manufacturers on the European or American continents is a hard task, but it can be managed if the means are available which will ensure to the manufacturer stability as regards price of fuel or power, and he is assured that the question of price and service shall not be used as a "pawn" in the game between party politicians as each election day comes round.

Monopolies are in many cases necessary for stability of service, particularly with electric supply; but if they are to be in the hands of a political party they may be used to such a purpose as will wreck the power of the manufacturer to compete with those abroad and eventually prove the ruin of the very purpose for which it was created.

The mainstay of any community is its power of production to support itself and to have a surplus with which to interest other communities.

To "make both ends meet" without something left over is not good for the welfare of any nation, and if the mainstay of London,—viz.: the ratepayer—is mulcted in heavy rates as the result of imprudent and ill-considered government, he cannot maintain his position in the world's markets, be it at home or abroad, and at the same time contribute his quota to the maintenance of the local government.

One can only conclude this article by expressing a wish that the decision to consolidate the electric power supply of London may be such as will satisfy that most important person, "the consumer."

MODERN GEAR-CUTTING MACHINERY

By Joseph Horner



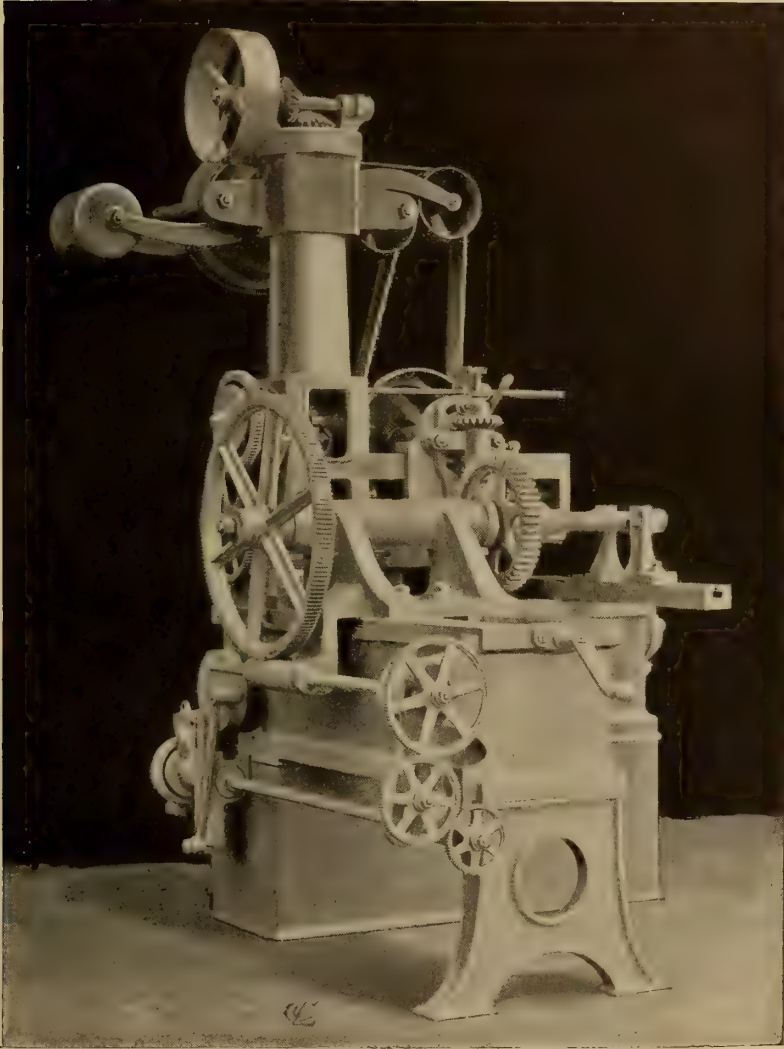
THE development of the gear-cutting machines is generally attributed to a laudable demand for teeth more accurate than those which could be cast. This is only a part of the truth. That growth is due in the main to the

improvements which have been effected in milling cutters, and particularly in the form type in which the backing-off is done from a centre not coincident with the centre of the cutter. The important result follows that constant regrinding of the teeth does not alter their sectional shape, so that the last wheel produced after the cutter has been ground for the last time has the teeth of the same section and size as those which were formed by the cutter when it first left the maker's hands. But in recent years the tendency has been towards the displacement of the service of the rotary cutter in the production of bevel gears, and to a lesser degree in that of spurs. A number of new machines operating single-edged reciprocating or planer tools have been designed besides a later group, the generating machines. Two great groups of machines, therefore, are now in use, those using revolving and those employing reciprocating cutting tools, and generating machines appropriate both kinds of cutters. Each group, however, embraces so many different classes that each would have to be

dealt with individually in any attempt at an exhaustive study of these machines. It is not, therefore, intended to cover this ground, besides which many of the machines of note have been already illustrated in this magazine, but to give some attention to the aspects of present developments.

The designs of gear-cutting machines and the methods of cutting gears are rapidly developing along the lines of specialization. Time was when there was for all practical issues only one kind of machine, that for producing spurs, bevels, and worms with milling cutters, variations in angle being provided in the cutter head. That machine is still a very useful one, and largely employed, but it is serviceable chiefly in the shops which can find only sufficient work for one type of machine, which must needs be universal in character. The objections to this type are the overhang of the wheel being cut on its horizontal arbor, whereas a vertical arbor with no overhang would be stiffer. Also the fact that bevel wheel teeth cannot by any possibility be cut more than approximately true, and then only by various settings and adjustments to angles. Finally, the correct cutting of worm gears by hobbing is impracticable.

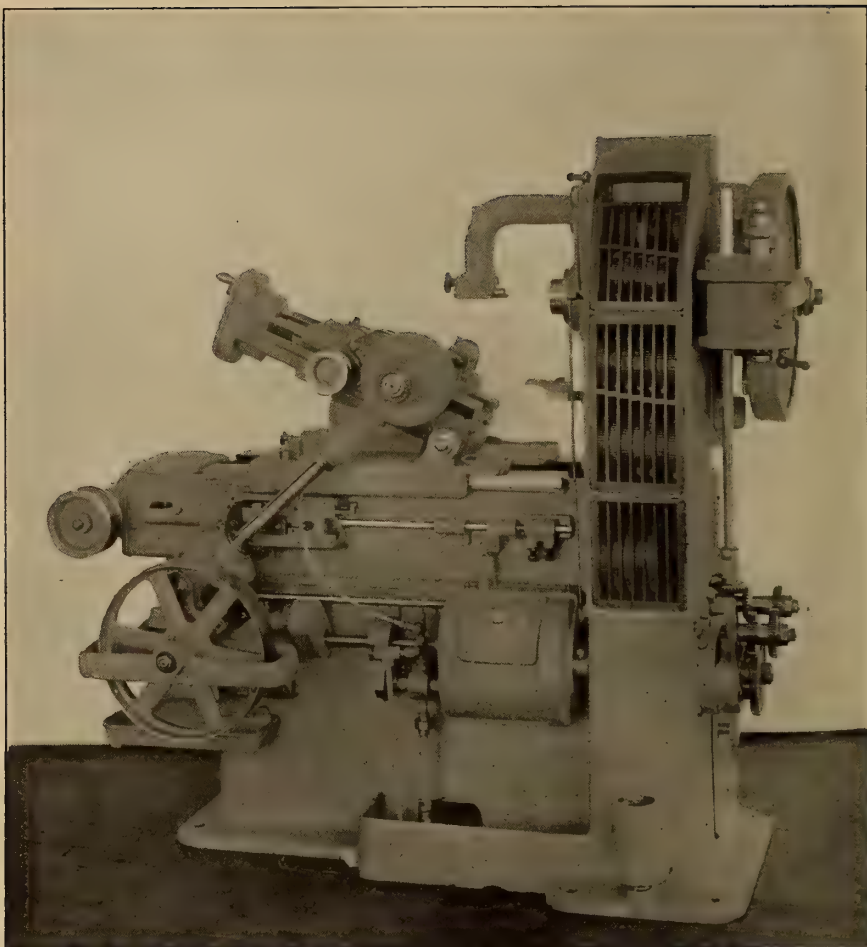
Another class of universal gear cutter is a pillar and knee type of milling machine. This, with a dividing universal head, has a wider range of utility than the previous one, because to the work of that machine the cutting of spirals and helical gears is added. But otherwise the same objections exist, and, further, the type is only capable of dealing with gears of small dimensions. A large num-



THE ORIGINAL SELLERS AUTOMATIC GEAR CUTTER AS SHOWN AT THE PARIS EXPOSITION OF 1867

ber of machines of related or independent types have come into rivalry with these two standard forms, being designed to avoid the numerous objectionable features which are inseparable from any one of universal character. There are two points of view from which these can be regarded, one that of the wheel types cut on them, the other that of the fundamental principle embodied in the design of the machines. Under the first head, that of wheel types, are included spur wheels, external

and internal, and racks, bevels, spiral gears, the latter including spirals, or screw gears, helicals, and the worm gears. The second point of view, that of principles of operation, includes the following:—The imparting of tooth profiles by milling cutters, profiles imparted by a form tooth in a planer type of machine, using a single-point reciprocating tool, the movements of which are controlled absolutely by the enlarged form tooth. Reciprocating tools operated without formers in generating machines, and

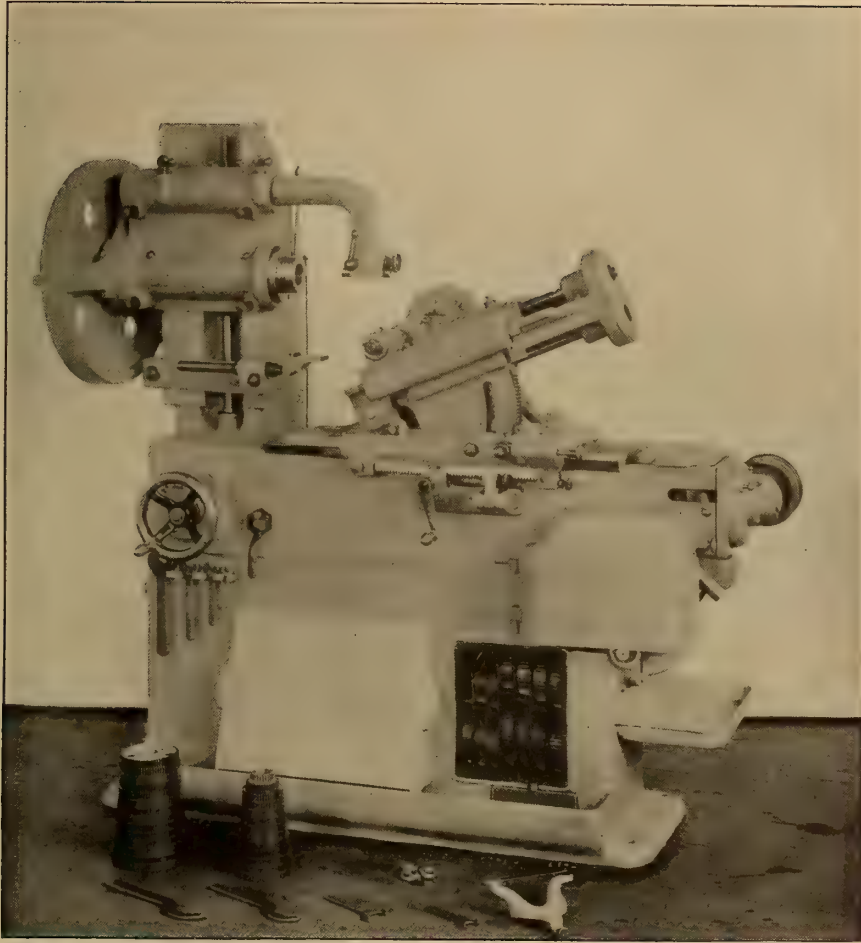


AUTOMATIC GEAR CUTTING MACHINE FOR SPUR AND BEVEL GEARS. BROWN & SHARPE MANUFACTURING CO., PROVIDENCE R. I.

rotating cutters employed in generating machines. These now constitute a distinct group, with numerous subtypes, but a few are represented by a single machine only. In the generating machines especially the most interesting developments have been taking place, and they probably represent the types which will predominate in the future.

Considering the subject of gears first from the point of view of new wheel types, the spurs, external and internal, with racks, include the largest numbers of gears made. The teeth of these are readily produced by milling cutters, so that there is

little rivalry to this method of formation. Provided the milling cutters used are correctly made in the first place, and backed off, this method of production satisfies the most exacting requirements. The Fellows gear shaper, however, is a successful machine in which spur wheel teeth and internal gears, as well as racks, are produced by generation. The cutter is a hardened steel gear wheel, the teeth of which have clearance, and operate with rotary and reciprocal movements, generating conjugate teeth. The cutter itself is generated from an emery wheel, the relative movements of the two repre-



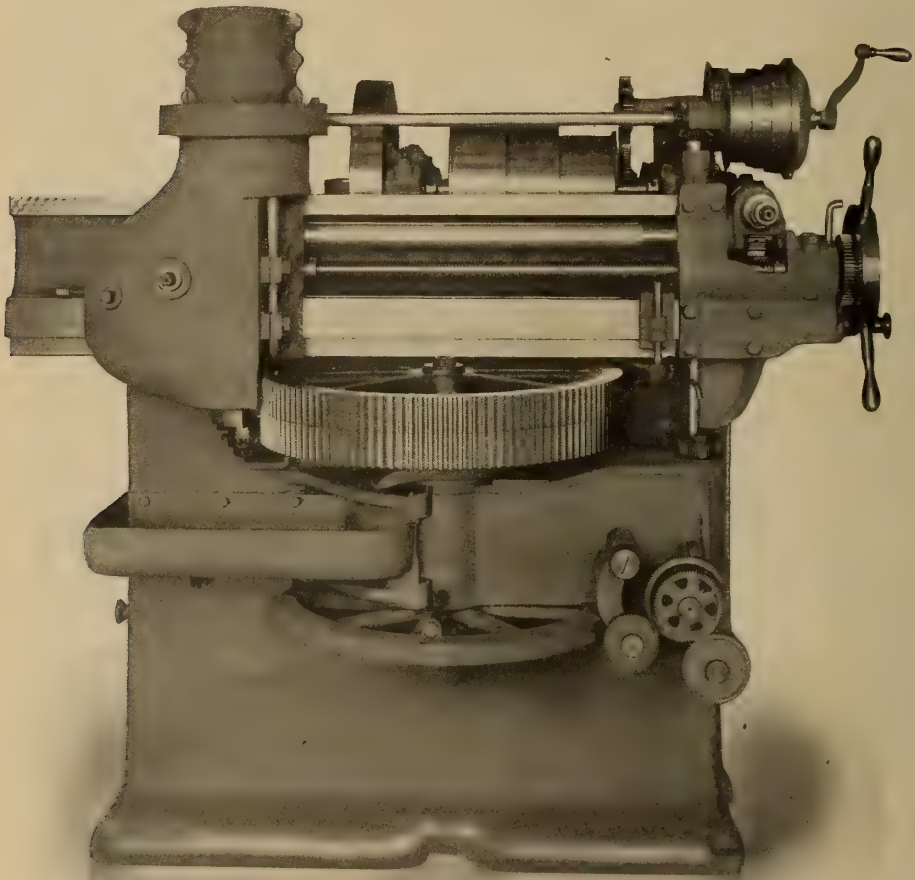
BROWN & SHARPE AUTOMATIC GEAR CUTTING MACHINE, REVERSE SIDE

senting the action of a rack and pinion. From this cutter all gears of the same pitch can be generated with absolute accuracy, precisely as a pinion would mould teeth in a blank of plastic material. With the exception of this machine, the developments of spur gear cutters, while retaining the rotary milling cutter, have taken place chiefly along secondary lines, such as automatic arrangements, provision for increasing output, either by adding to the number of blanks being simultaneously operated on, or by using multiple cutters; by stiffening up, and by arrangements for heavier cutting, and finally by restricting the duties of

such machines to the cutting of spurs and racks only, so that the design and movements are subservient to one result. Some of these machines embody the vertical work arbor, others the horizontal. Excepting for the divisions for pitch, the blank remains stationary, and the cutter traverses along a slide, and is thus perfectly supported under heavy duty. A good range of speeds and feeds is available by change gears, and the pitching is effected by change gears and dividing wheel. Stops produce the reversals, quick return is fitted, and the dividing motion is in the best machines automatic, without using a notched division plate. The

pitching is independent of the feed and speed of cutter. The dividing wheel is of large diameter, with provision for taking up slack. Generally, too, the machines are built very compactly, with box base, which

chine where the cutter is carried in a reciprocating slide, provision is readily made for internal teeth. It takes the form of a holder attached to the slide, and which carries the cutter in an overhanging nose that

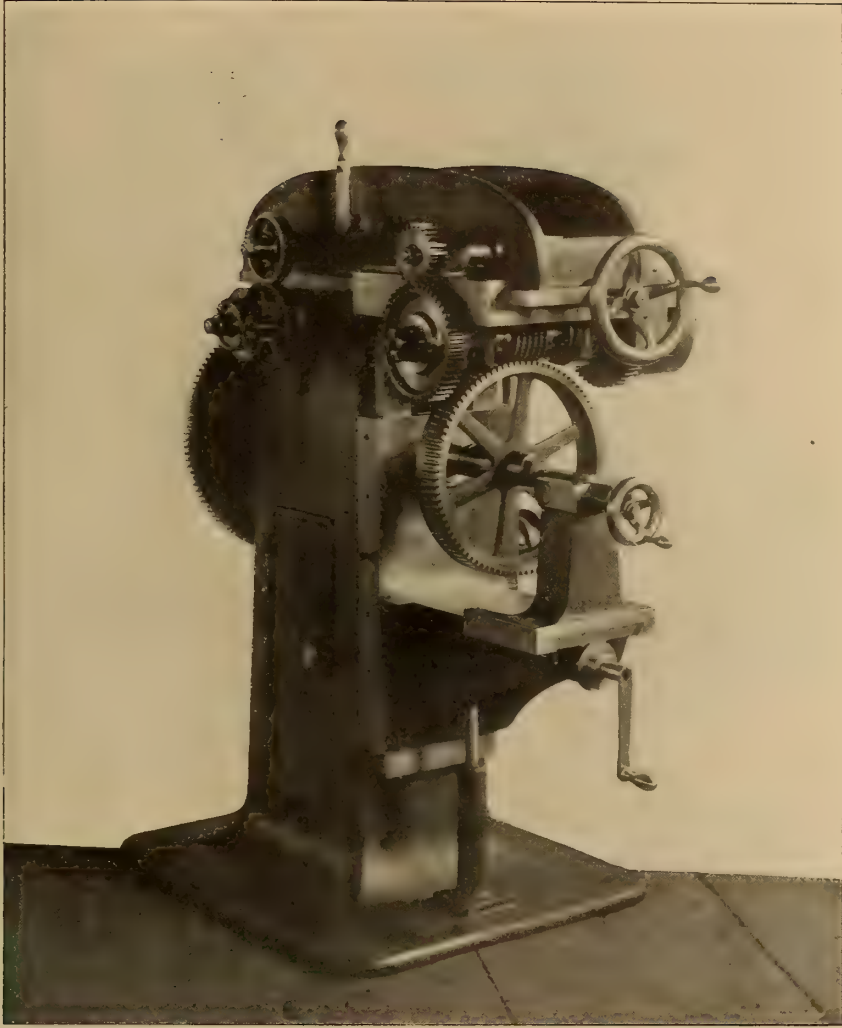


THE FELLOWS GEAR SHAPER, GENERATING THE TEETH FROM A CONJUGATING CUTTER. THE FELLOWS GEAR SHAPER CO., SPRINGFIELD, VERMONT

contains rack cupboards for the reception of the change gears.

Internal spur gears are not required so frequently as the external. They cannot be cut on the older type of universal machine, in which the spindle head is adjusted along the bed, because the cutter spindle blocks the way. But in a spur-gear ma-

chine enters the internal gear, and is fed through it with a suitable train of spur gears operated from the main cutter spindle. No provision exists for cutting straight racks in the universal machines of old-fashioned type. They are cut on universal milling machines by the use of an extra attachment, having a cutter spindle driven

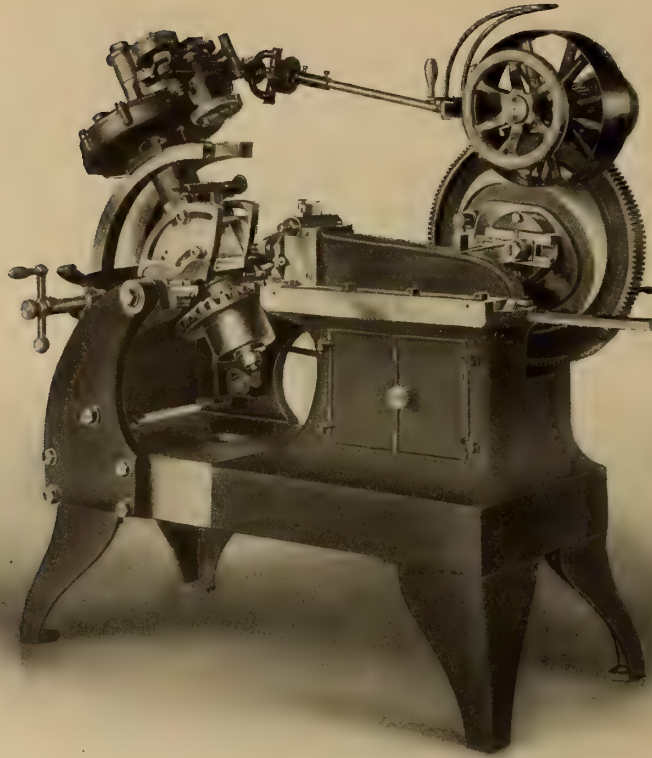


SWASEY'S AUTOMATIC GEAR CUTTER. THE WARNER & SWASEY CO., CLEVELAND, OHIO.

The revolving cutters have the form for the rack tooth, and generate the correct form for any wheel by moving longitudinally on their axis as they revolve.

through gears from the main cutter spindle. The pitching is done through change gears and a locking disc. Several racks, side by side, may be having teeth cut through at a single traverse. There are also several machines designed for rack cutting alone, in which as many as a dozen racks may often be handled at once. In these machines, too, the multiple cutters show to much advantage, being of more extensive service than when employed for spur gears.

The bevel gears, however, have occasioned more developments in machines than other forms. It seems curious that the greatest number of bevel wheels even now have their teeth produced with rotary cutters, and that a generation ago there was practically no other method practiced. In saying this we are aware that pioneer bevel gear planers were in existence about fifty years ago, but it is nevertheless only during the last two or three decades that the



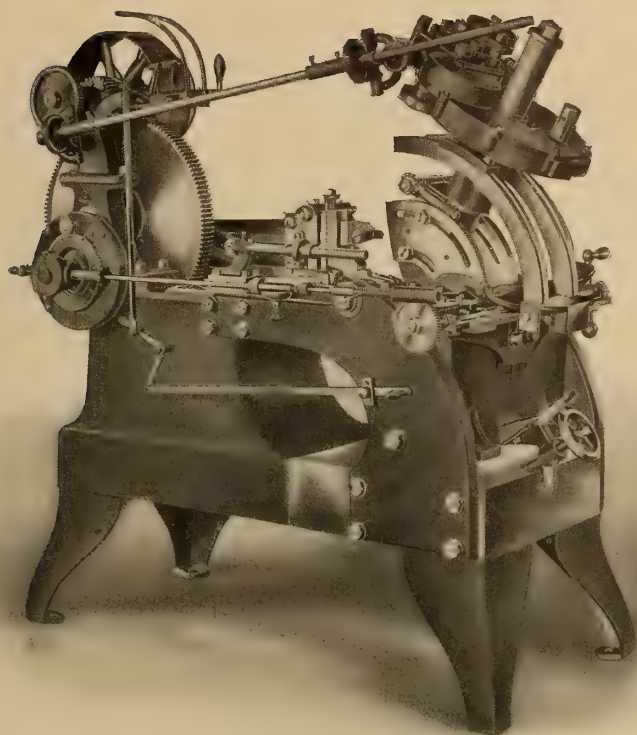
BILGRAM GEAR CUTTING MACHINE FOR GENERATING BEVEL GEAR TEETH BY ENVELOPMENT. FRONT SIDE. HUGO BILGRAM, PHILADELPHIA

practice has become familiar in the leading shops.

In producing bevel wheel teeth with milling cutters the impossible ideal is the production of curves which continually change by means of cutters the sections of which do not change. The approximation to this is obtained by sundry adjustments between cutters and work, with or without subsequent filing. The results are largely dependent on the deftness and experience of the machine attendant. Well-formed, if not absolutely perfect, teeth are obtainable, but at the sacrifice of time, and with so much of uncertainty that the good practice is frequently adopted of testing the gears by running them together on temporary shafts. The system is, therefore, not in harmony with present day requirements respecting toothed gears.

In any machine designed for cutting bevels, settings for two sets of angles have to be made. That one for the wheel section is comparatively simple, that for the tooth flanks gives trouble.

In machines using rotary cutters provision has to be made for setting the cutter in the two directions corresponding with these two elements. But while the first is readily effected, the second does not produce even an approximately accurate profile, because of the difference in the profile of the rigid cutter and the changing profiles of the teeth. Cutters which embody a compromise are, therefore, selected, such as one having a profile corresponding with that of the teeth at a distance of one-third of the teeth length measured from the larger end. Then also the gear has either to be rolled a little to permit of the re-



BILGRAM BEVEL GEAR CUTTING MACHINE. REVERSE SIDE

removal of some excess from the faces at the smaller end, or the excess must be filed. Such devices are obviously makeshift attempts to enable a machine to perform functions that are not embodied in its essential design. The first obvious solution of this difficulty is to design a planing machine in which all the strokes of a single-edged planer tool shall be made to move in paths terminating in a fixed point, the apex of a cone of which the gear blank forms a frustum. The principle is obvious and simple, but it has been worked out in more than half a dozen distinct ways in good, commercially successful machines. Most of them have been already illustrated in the pages of this magazine. At present we merely note that, though there are numerous ways of arranging the blanks and the cutting tool or tools, all these machines fall under one of two heads. They either use a form

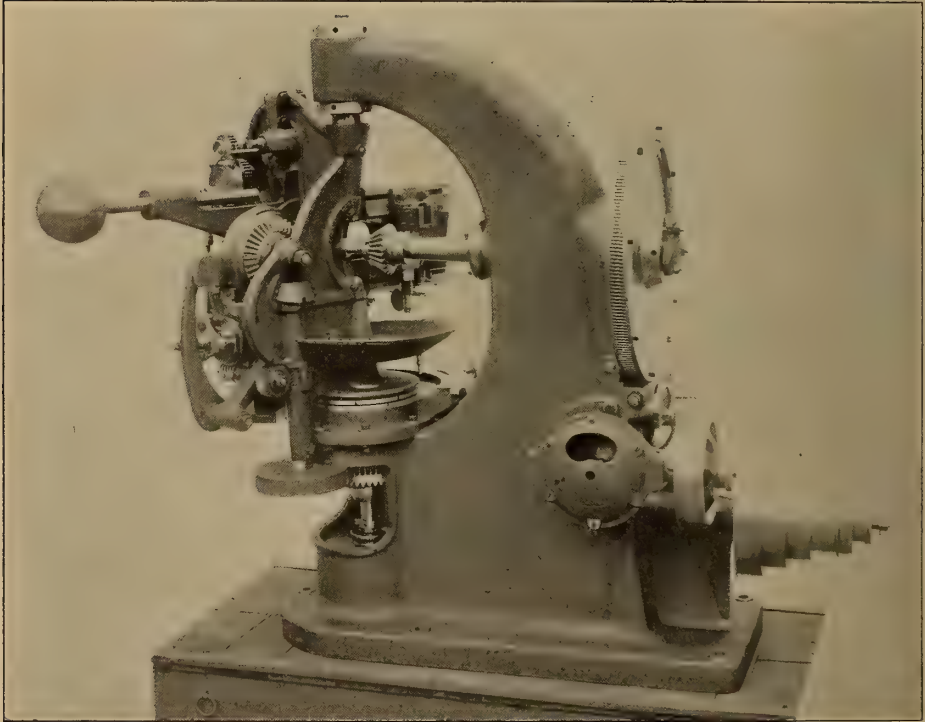
tooth, or they generate the tooth shapes by virtue of the mechanism embodied in their design. The first-named are much simpler and less ingenious than the second. From this point of view also the subject of tooth profiles has to be settled, because double-curve teeth cannot be generated, but must be produced by a form tooth.

If the form machines had always yielded reliable results less would have been heard of the generating machines. It seems a simple matter to make an accurate form tooth, say three times larger than those on the actual wheel, and to cut the teeth of the latter by its guidance. But errors arise in the preparation of the form and in the setting up and working of the machines, so that the gears produced have not given invariable satisfaction, and have sometimes been less accurate than those made by rotary cutters. At the same time, the

demands on high-speed gears have become more exacting, especially in connection with electrical work and machine tools. But chiefly, perhaps, the increasing use of single-curve teeth must be credited with the increasing demand for generating machines. And, again, the growth of these has been favourable to the gradual displacement of cycloidal by

ments which are embodied in the design itself. The cutting is done by a reciprocating, shaper-like tool, moving toward the apex of the cone of the wheel.

This apex is situated in the vertical axis of the machine, the axis which passes through the centre of the boss in the top of the framing and the centre of the table below. The wheel

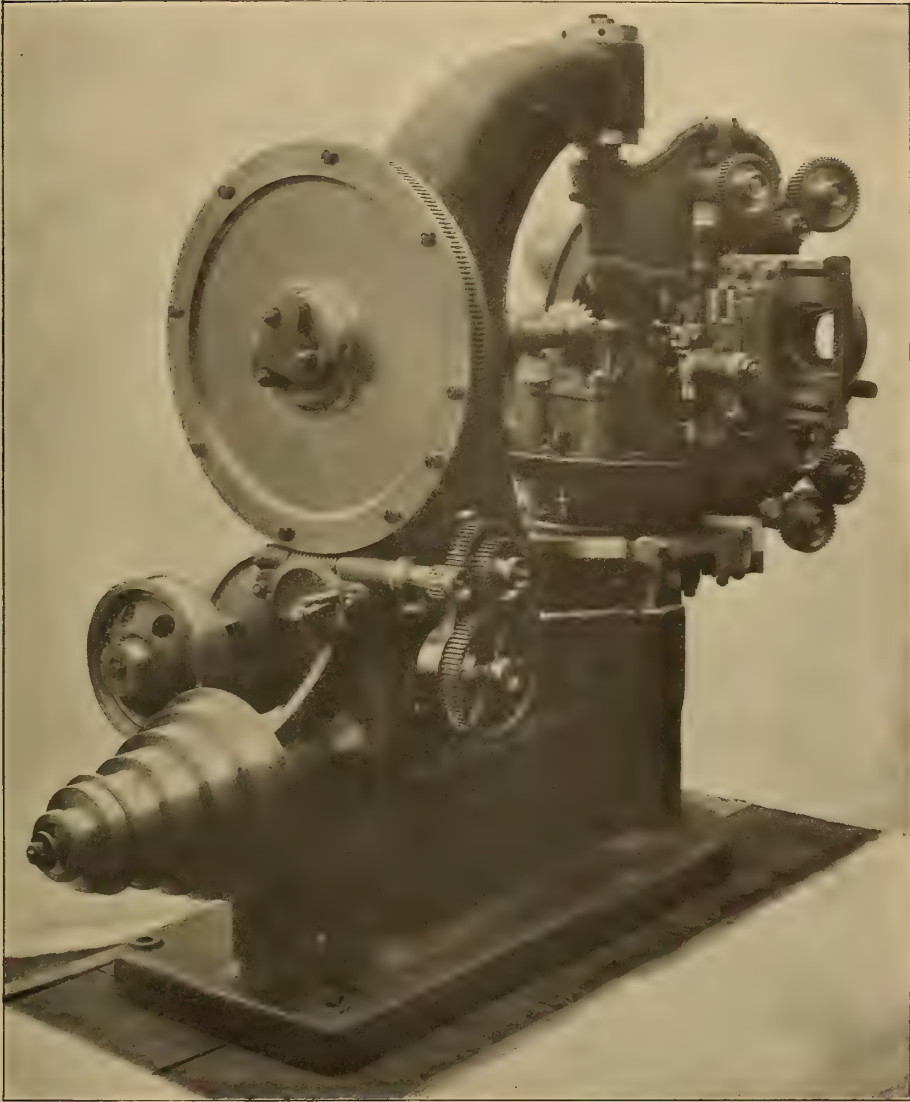


BEVEL-GEAR GENERATING MACHINE. E. DUBOSC, TURIN

involute teeth. The Bilgram was the first of the generators, "roll cones" being adopted in it. Adjustable planer arms, regulated by links and connected mechanism, are embodied in the Robey-Smith. In the Beale machine the teeth are produced by cutters that represent the angle of a rack tooth.

A new machine for cutting bevel gears which demands attention is that designed by Edmondo Dubosc, of Turin, Italy, which contains many ingenious features. This machine generates involute teeth by move-

blank is carried on a horizontal shaft which is a prolongation of the axis of the dividing worm wheel, this shaft intersecting the vertical axis. Two main elements in the design are the horizontal arm which carries the tool slide, and the vertical framing pivoted to rock in a horizontal plane about the vertical axis passing through the apex of the cone for all wheels. The horizontal arm, which carries the tool slide, swings in a vertical plane about the horizontal axis of the blank and the dividing wheel, and by the combination of

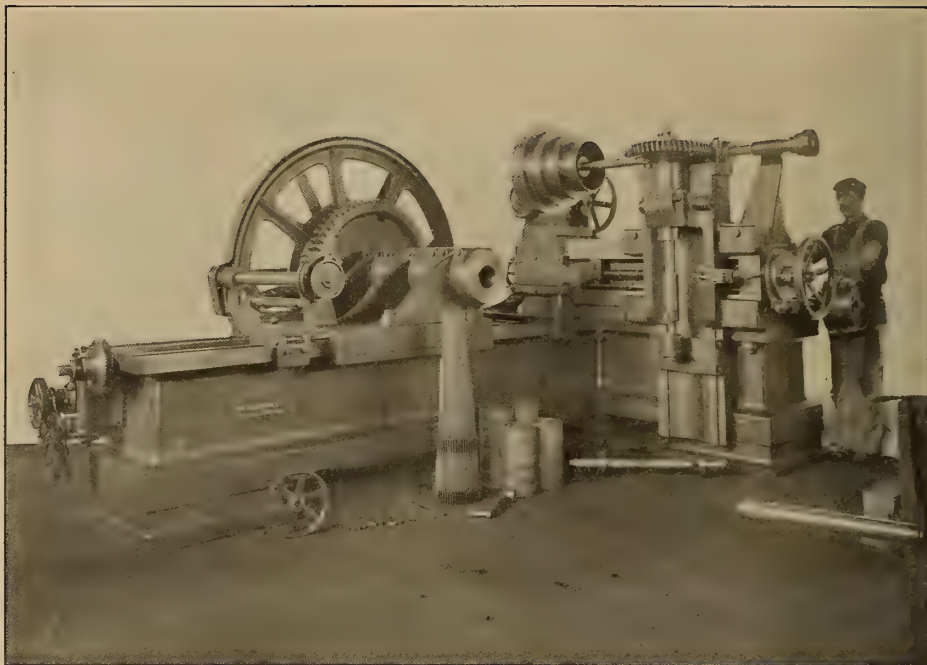


BEVEL-GEAR GENERATING MACHINE. E. DUBOSC, TURIN

these two movements the tooth is generated, one giving the feed in the direction of the height of the teeth and the other the outline or curve of the flanks of the teeth.

The action, in brief, is this: The tool reciprocates continually, and cuts one side of a single-curve tooth under the coercion of the vertical and horizontal arms. When one side of one tooth has been cut the wheel blank is turned automatically round

a distance equal to the pitch, and the same cutting operation is gone through for the next tooth, and so on until all of one side of all the teeth are done. Then the position of the tool is changed to cut all the other sides, and the feed mechanism is reversed. As each of these movements is variable, there are three sets of change wheels by which they are effected. That is, there is one set for pitching or dividing the teeth,



SPUR AND BEVEL-GEAR CUTTING MACHINE, CAPACITY 120 INCHES. THE PRATT & WHITNEY CO., HARTFORD, CONN

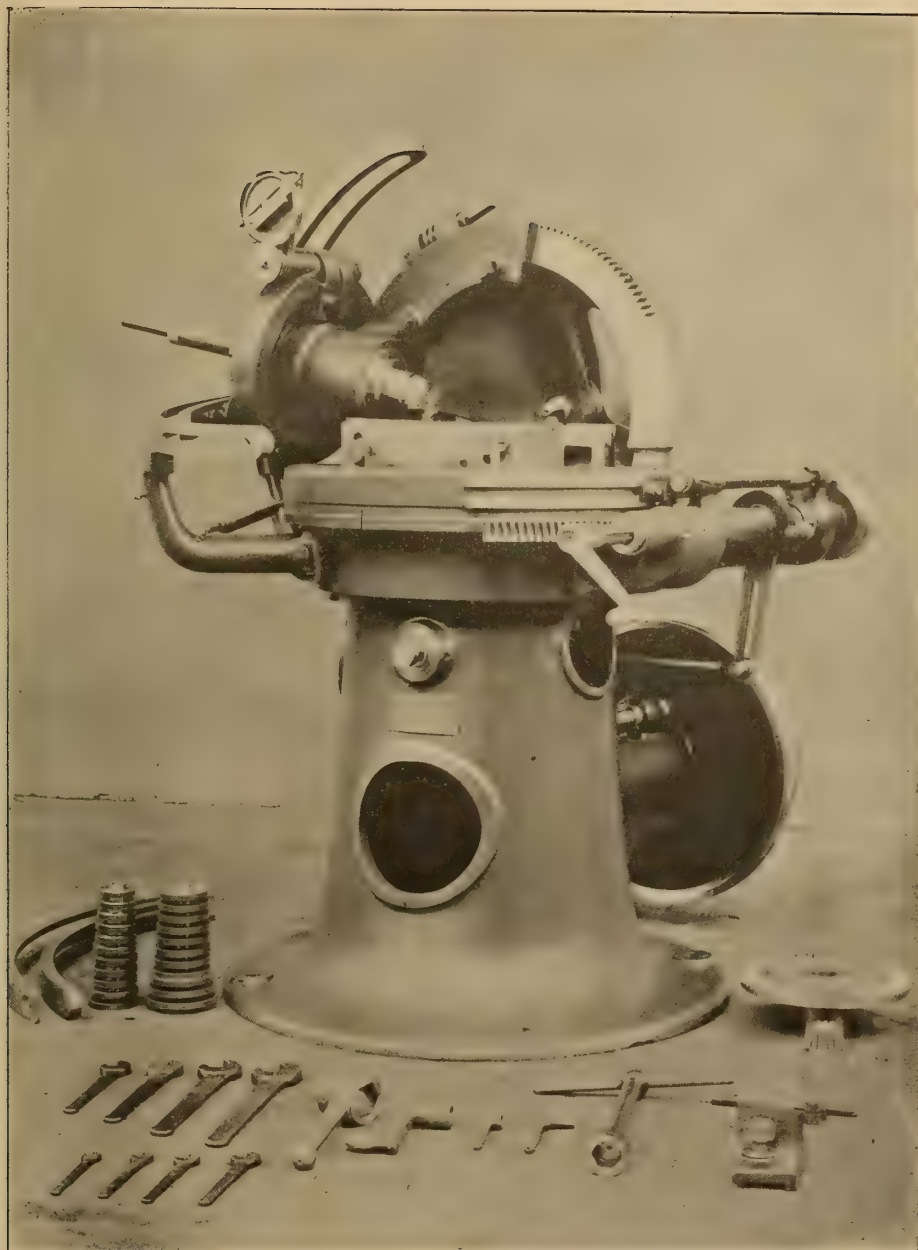
another set for imparting their dimensions and a third for their contours, or profiles. The machine is, therefore, a generating one absolutely. In order to facilitate the setting of the machine suitable charts are prepared for use with it.

Another recent generating machine is the Ducommun, for which Alfred Herbert, Ltd., are the English agents. The basis of the generator is a crown gear. The blank is inclined at the correct cone angle and moved in a path corresponding with that through which it would travel if rolled upon the crown gear. The teeth are then planed with a single-edged, broad-faced tool, operated by a crank arm in the base of the machine. Horizontal and vertical adjustments are effected by the toothed and graduated sectors seen. The machine is semi-automatic, the feeds being self-acting, and the pitching by change gears and division plate.

Single helical gears are used to a much greater extent on the Continent than in Britain, where double

helicals are preferred on the ground that the lateral pressures are balanced between the right and left-hand teeth, and that they reinforce and stiffen each other. For these reasons most wheels of this kind have been moulded by machine. But this is not satisfactory for small gears or for good work. Many of the latter, therefore, are produced by cutting two single helical wheels and bolting them together in the middle plane. These are satisfactory to a certain extent, but they do not meet the case of split wheels placed over their shafts and bolted thereon, and present design favours the use of such wheels for obvious reasons to a much greater extent than that of a few years since did. The difficulty is being got over in two ways, by cutting without breaking the continuity of the teeth at the apex, and also by parting the teeth there.

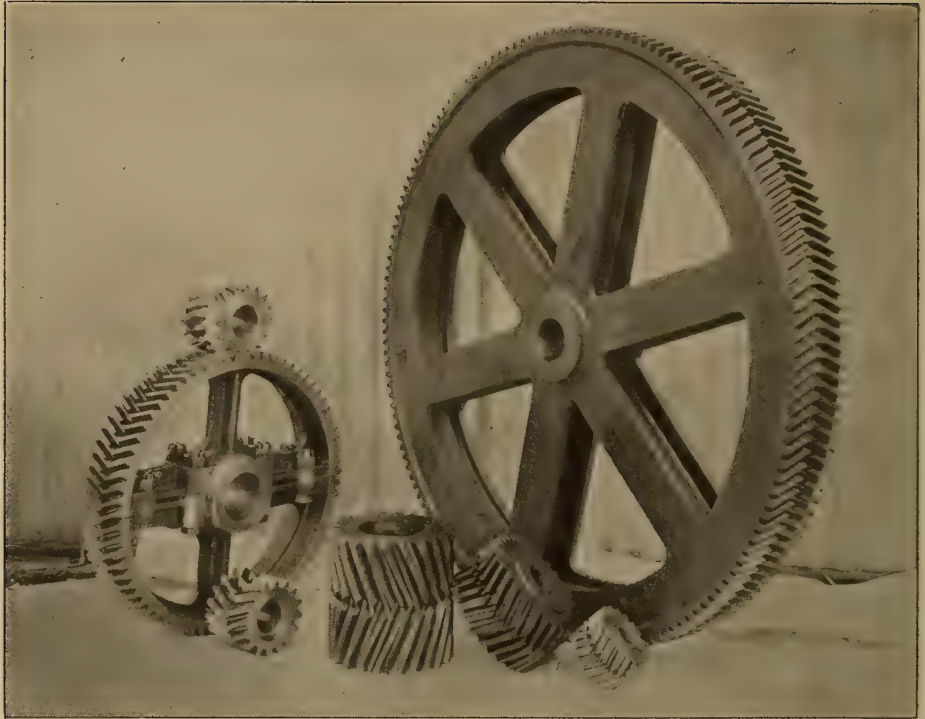
A recent development in the cutting of such wheels is that under the Wüst patent, manufactured in England by the Power Plant Company,



DUCOMMUN SEMI-AUTOMATIC BEVEL GEAR SHAPER. ALFRED HERBERT, LTD., COVENTRY

Ltd. A cut is run round the middle plane of the wheels as deep as the teeth, and the tool clears itself in this in cutting the right and left-hand teeth. Besides this the teeth are staggered; that is, the right and

left-hand teeth are shifted in relation to each other by a distance equal to half the pitch. This has the same effect as halving the pitch and doubling the number of teeth in straight wheels, so conducting to



GROUP OF WUST DOUBLE HELICAL GEARS, SPLIT AND SOLID. THE POWER PLANT CO., LONDON AND WEST DRAYTON

smooth engagements. The machine for cutting the wheels is shown in the illustration, with a cast-steel wheel, 70 inches in diameter by 10 inches wide, being cut. The two cutter heads on the bed of the machine each operate on one set of teeth.

In a previous article mention was made by the writer of new helical gears in which the number of sets of teeth are increased beyond the regulation two, and examples were given of these, in connection with the Liège Exhibition.

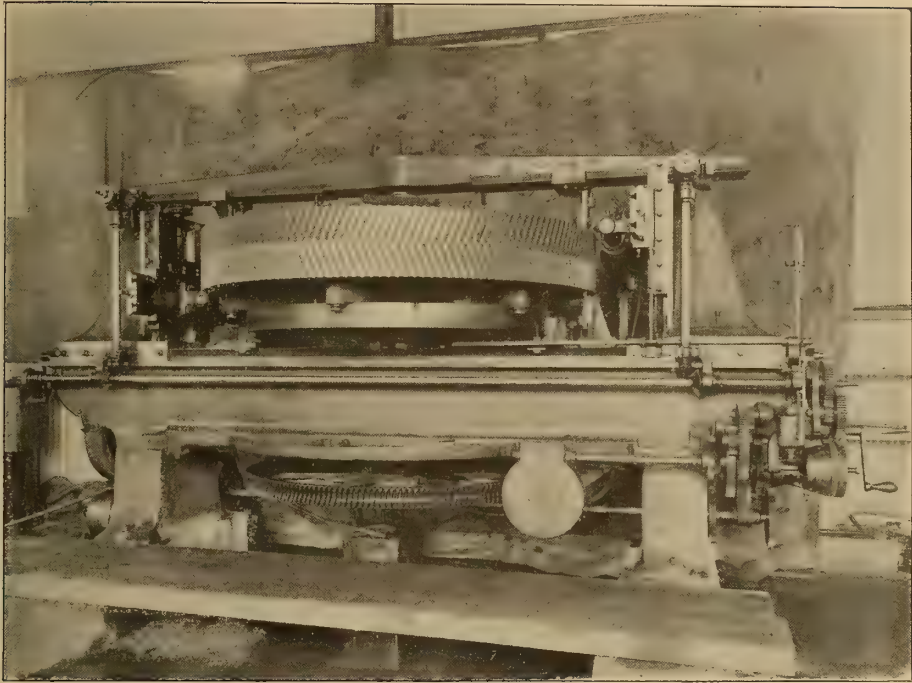
The spiral gears, or screw gears, are work for the universal head on the milling machine, which combines a screw of definite lead with change wheels, and a division plate by which the gears are rotated under a cutter and pitched.

In most machines the table is set to the angle of spiral. The mechanism is self-acting during the cutting of a single tooth space, but

the index peg has to be set in the suitable hole in the division plate at each time of pitching. The cutters used are selected to correspond with the normal pitch, or that measured at right angles with the course of the spiral teeth, and the same cutter must be used for gears that have to run together, even though their circular pitches may differ widely from each other. The same cutters are, therefore, used as for spurs having the same normal pitch.

Worm gears are true spiral gears, though the fact is disguised by the extremely short lead of the spiral of the worm and the extremely long lead of the spiral of the wheel teeth, and also by the great discrepancy in the numbers of threads in each. For these reasons they have to be manufactured by methods which differ from those adopted in helical wheels.

The worms are often cut in the lathe, provided the pitch is not very

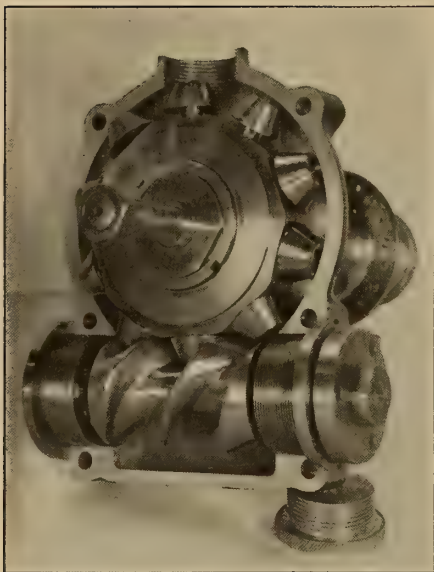


CUTTING TWO SETS OF HELICAL TEETH ON WORM GEAR. POWER-PLANT CO., WEST DRAYTON.

steep. All single-threaded worms can be done thus. Worms with two threads and over are done in the milling machine, using a rotary cutter suitable for a rack and a swivel head, or in special worm milling machines. The cutting of the wheel teeth is done in the milling machine only when the teeth are straight, i. e., not made concave, to form envelopes of the worm. When of this shape they are almost invariably hobbled, using a hob shaped like the worm, but notched, backed-off, and hardened. The obvious result is that the wheel teeth are produced precisely as they would be if the teeth were of a plastic material and moulded into shape by the worm. To produce correct results means must be provided for rotating the worm wheel blank in relation to the worm exactly as the gears will have to run when finished. It is practicable to do this without special mechanism, provided the precaution is taken to gash or rough out the tooth spaces first. But several machines embody driving mechanism,

and in some of these a single cutter is used, which, however, is only practicable when the driving is done by change gears.

The Globoid worm gear is a novelty by which rolling motion is substituted for sliding. The teeth of the wheel which takes the place of the ordinary one are conical pins. If they were an integral part of the wheel they would, of course, set up severe friction, due to their long contact. But being made free to revolve on pins driven into the wheel rim, they possess rolling, non-frictional contact. The losses due to friction, which include those due to the bearings, are low, so that the efficiency is from 90 to 95 per cent. This result must be credited partly to the fitting and lubrication of the rollers. They run on studs of tough steel, case-hardened, and these, with their rollers, are ground to gauge. The entire gear runs in a bath of oil, and in the usual design the worm is lowermost. The rollers are automatically lifted from their seats at



GLOBOID WORM-GEAR SYSTEM. POWER PLANT CO., LTD.

each revolution, permitting of the entrance of oil between the rollers and studs, which prevents risk of seizing of the rollers on their pins. The shafts of worm and wheel are of steel, case-hardened and ground. The axial pressure of the wheel is taken on hardened thrust discs, that of the worm on ball bearings at both ends of the shaft. The worm shaft runs in bearings of hard phosphor-bronze. The durability of these gears is very good.

The term "globoid" refers to the form of the worm in longitudinal section. That is, the worm in that section is an envelope of as much of the arc of the wheel as it embraces. As the wheel teeth are not curved, but have plane edges, and do not form envelopes of the worm, the appearance of the latter is skeleton-like and peculiar.

We now glance at the principles of the operations involved in the machines for cutting gears.

Tooth profiles imparted by milling cutters have, when their use is consistent with sufficiently accurate results, the merit of simplicity. The eight cutters for involutes and the

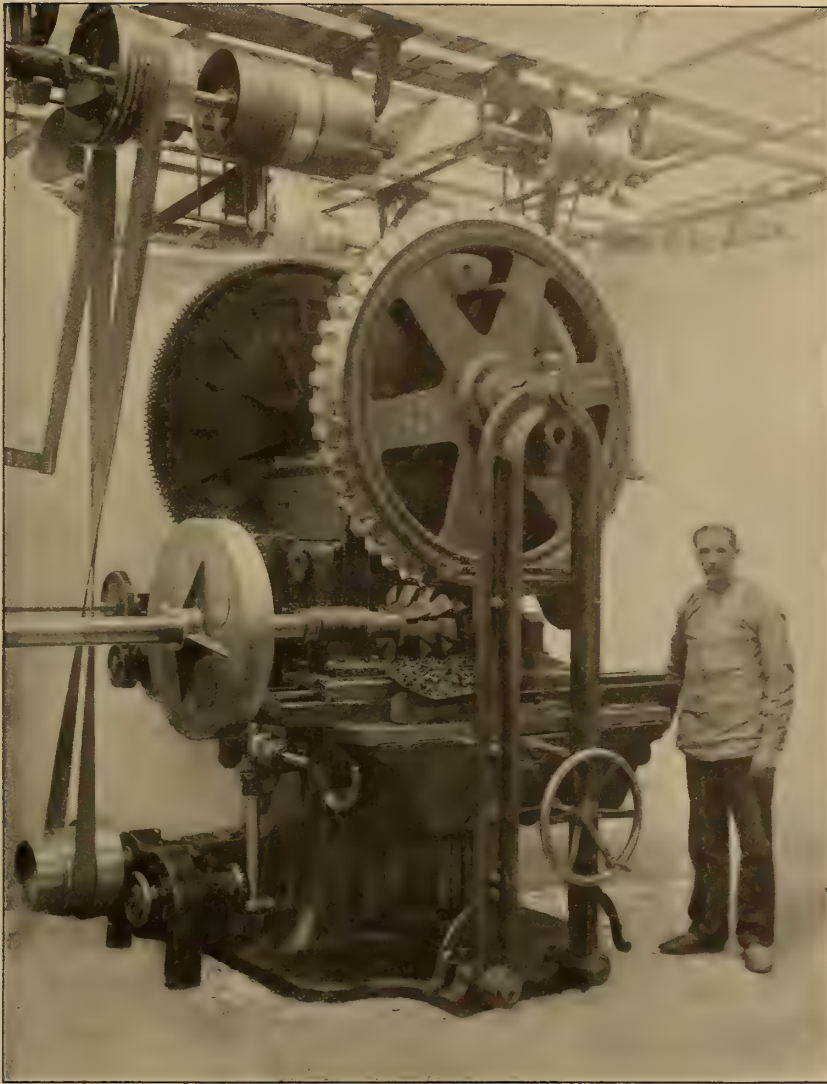
twenty-four for cycloidal teeth cutting all the wheels in a single pitch standardize the practice. There is, of course, some little compromise inevitable, when either eight or twenty-four cutters have to produce all the range of teeth from an 11-toothed pinion to a rack. But it is so slight that the province of the rotary cutters has scarcely been invaded when spur wheels only are in question. The Fellows machine, as mentioned, is the only notable instance of rivalry.

When firms are committed to double-curve teeth they cannot avail themselves of generating machines, but the choice must lie between rotary cutters and form planers. But the latter are not adaptable to the same extent as circular milling cutters are. We have seen that the same cutters can be used for helical and worm gears and internal spurs, as well as the ordinary spurs with internal teeth. There is little trouble in setting cutters and gears centrally, and the cutters operate on both sides of the tooth space simultaneously.

Profiles imparted by means of a form tooth in a planer type of machine constitute a device which scores in bevel gear cutting, for which rotary cutters are ill adapted under any conditions. One can only say with



GLOBOID WORM-GEAR COMBINED WITH DOUBLE-HELICAL GEARS. REDUCTION RATIO 40 TO 1. THE POWER PLANT CO., LTD.



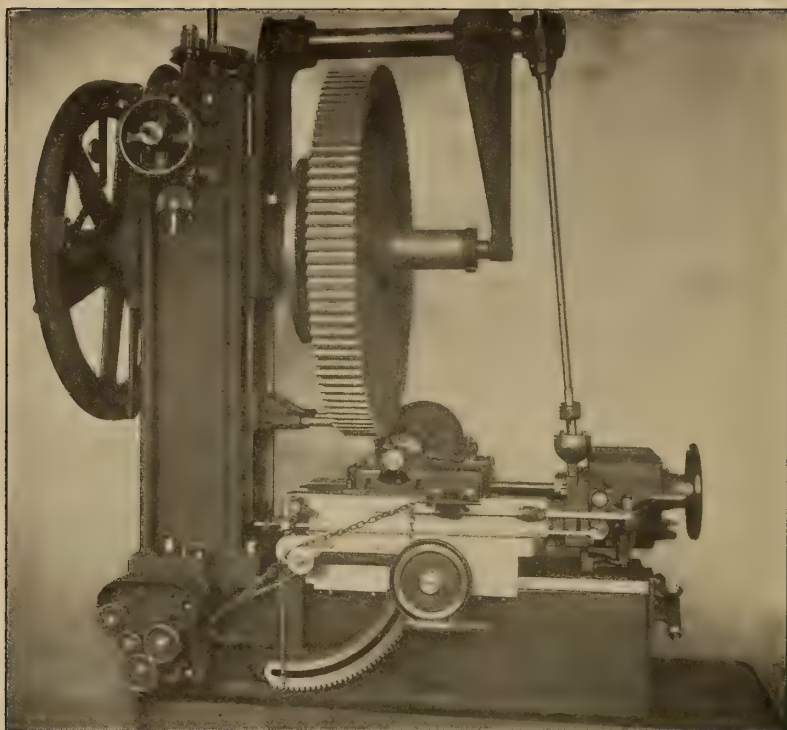
UNIVERSAL² GEAR CUTTING MACHINE HOBGING A WORM-WHEEL. J. E. REINECKER, CHEMNITZ-GABLENZ

regard to these that some conditions are not so bad as others. The least favourable are those in which teeth are wide, with corresponding great differences in the sizes of teeth on the major and minor diameters.

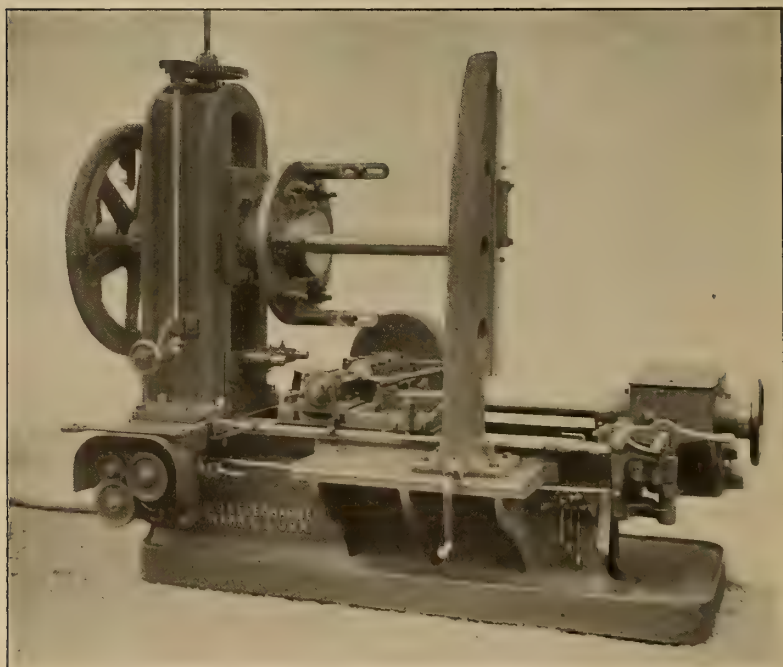
The principal machines of this type resemble and differ from each other in the following particulars:—

The form tooth is the central and essential element. If the reciprocating slide which carries the tool travels in a strictly linear direction,

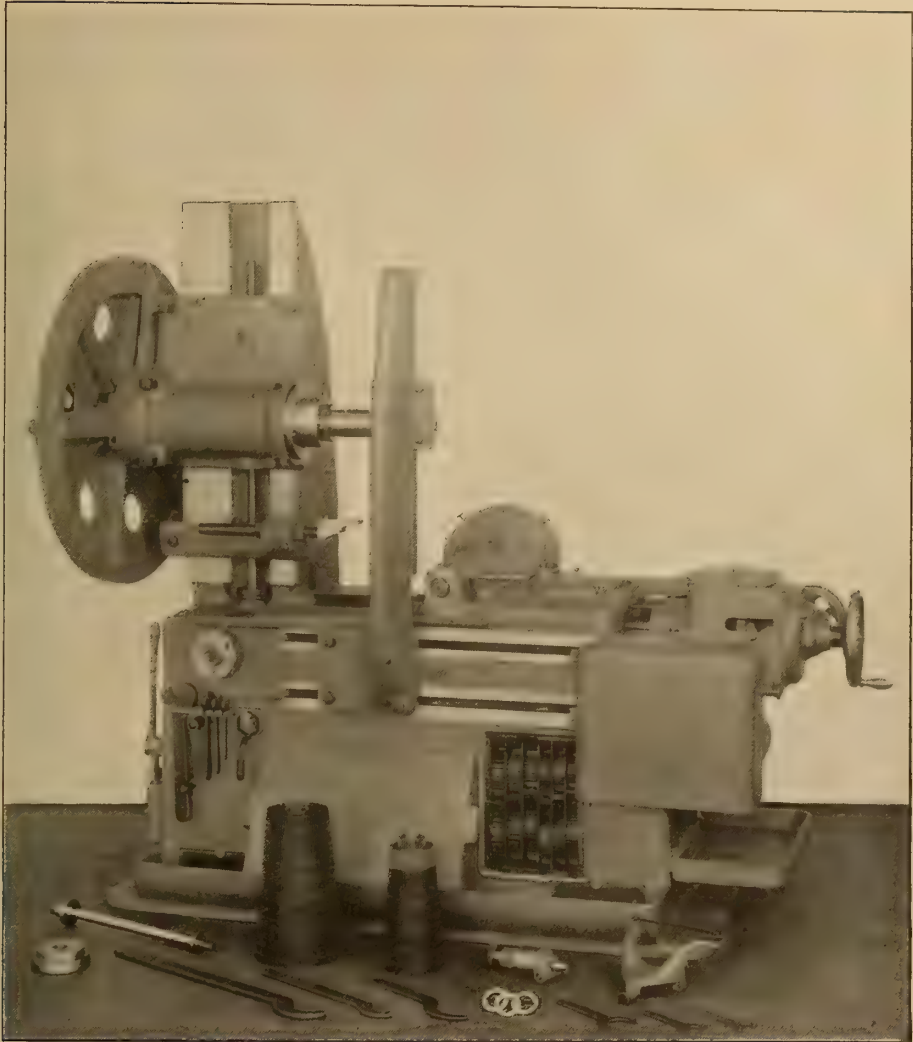
the movements of the wheel blank have to be coerced by the edge of the former. Or the arms which carry the tool-box, or boxes, may be coerced by the former. This lateral movement is in addition to that movement of the blank or arm which must take place to impart the bevel of the wheel in section. Some machines cut one side only of one tooth, others have two arms to cut both sides of one tooth at a time. Some machines are of vertical face type; that is, the



LARGE SPUR AND BEVEL-GEAR CUTTING MACHINE. CAPACITY 74-IN. DIAMETER, 14-IN. FACE.
GOULD & EBERHARDT, NEWARK, N. J.



IMPROVED GEAR-CUTTING MACHINE. GOULD & EBERHARDT, NEWARK, N. J.



AUTOMATIC GEAR-CUTTING MACHINE FOR GEARS UP TO 48-INCH DIAMETER, 10-INCH FACE. ARRANGED FOR USING OIL PUMP. BROWN & SHARPE MANUFACTURING CO., PROVIDENCE, R. I.

quadrant which carries the arbor for the blank is pivoted on the face of the machine standard. Others are horizontal, the quadrant moving on a horizontal face round a vertical pivot. Others, again, pivot round a horizontal pin, adjustments being effected against fixed quadrants embodied in the machine framings. A form machine which stands alone is the Rice, in which an entire master wheel is used about five times larger than the gear to be cut, and a rotary cutter is used which does not traverse.

Reciprocating tools operated without formers in generating machines embody some extremely interesting studies, in the manner of the evolution of definite tooth shapes without any semblance of a pattern, either in the shape of form or cutter. The cutters are always either single-pointed shaping tools, or wedge-shaped tools, or rotary cutters having plane faces. The fundamental idea around which the machines are designed is the crown bevel gear, in which the pitch plane is an absolute

plane, and the tooth form, an octoid. In the Bilgram machine the cutting tool always moves in one rectilinear path, and the arbor which carries the wheel blank has its movements controlled by an evolver or roll cone. The result is that the movement of the blank is partly an oscillation in a vertical plane for the bevel of the wheel section, and of a rolling on the pitch surface which gives the flank adjustments. Provisions for wheels of different sizes is made by separate evolvers of different radii, though as in standard cutters, one suffices for wheels of approximate dimensions. This machine stands as the sole representative of its class.

The preparation of blanks for the machine is an important detail because there is no pitch line struck from which to work, but exact pitch diameter depends on the diameter to which the tooth points are turned. Practically diameters are usually determined on the basis of diametral pitch, which is applicable equally to wheels having either involute or cycloidal tooth curves, circular pitch being used mostly in the case of worm and screw gears. Diametral pitch avoids small fractions, or full or bare dimensions in pitch diameter,

and small fractions in length of tooth above and below pitch line. Diameter and pitch are related in whole numbers, and addendum and dedendum are equal parts in the terms of the pitch. These relations are all that are required in the case of spur wheels. In bevels three angles are wanted in addition, the angle of the pitch cones, which is the basis from which the sectional forms are struck, the angle of the root or dedendum cone, and that of the point or addendum, and the angles of the tooth ends. These are struck to full size and templets made therefrom by which the turning of the blanks is checked. For turning bevel wheels in quantity the turret lathe affords economical facilities. In the case of very light gear wheels such as those used for change gears and worm gears, the rims are liable to become distorted by clamping or bolting to the face plate of a lathe, while an arbor through the centre does not provide sufficient stiffness, so that the wheel rim chatters. In such cases the milling machine may be substituted, the blank being rotated against a milling cutter which shapes the periphery and the faces and edges at once.

CONSTRUCTION-INSPECTION OF BOILERS AND ENGINES

III.—THE TESTS FOR EFFICIENCY

By J. R. Thompson



OUR engines and boilers, which we have followed in previous articles through all their stages of construction, have been delivered and put down upon their permanent site. The masonry and brickwork are completed and finished off, the internal plastering (if any) and the flooring and woodwork of the engine room are absolutely done with. The dust and dirt, the inevitable accompaniment of these last stages of the inside work, are finally removed, and the more or less decorated building in which the new motive power is installed is subjected to a thorough cleansing.

Following upon this, the main and subsidiary bearings have all been taken down, carefully wiped over and replaced, their lubricators and oil-pipes cleaned out, and the last remnants of gritty dust left from the building operations cleansed from their internal surfaces.

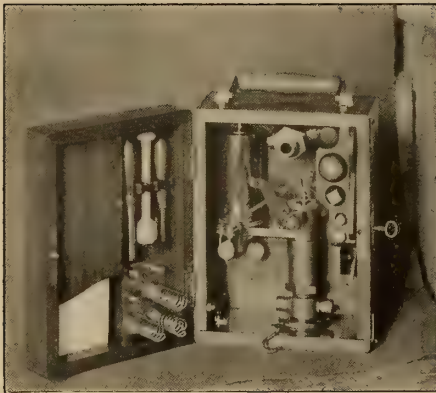
The importance of this precautionary measure will be best appreciated by those who have suffered from the annoying consequences of a sudden pull-up in the middle of a test run. "Only a bit of dirt in the big-end, Sir," reports the mechanic cheerfully, as you grimly stand by and see the results of several hours' careful work, weighing, measuring, and calibrating, rendered utterly use-

less. You have, perhaps, evaporated several tons of water under trial conditions, and are busily engaged in your preliminary comparison of "water evaporated vs. water accounted for in the indicator diagram." All is going smoothly, no haste, no fuss, your results are just beginning to come in, when a sudden and unauthorized "shut-down," to the accompaniment of a smoking-hot crank-pin, brings you the unwelcome assurance that the whole thing will have to be gone through again, all because of that little speck of builders' grit on the crank-pin.

The inspector, of course, does not make his steam and efficiency tests until advised by the contractor that the boilers and engines are completed and have been running on the load for a certain length of time, and that he is desirous of having them taken over by the purchasers. On the latter's behalf, therefore, the inspector attends, prepared to ascertain by actual tests whether the specification has been complied with, and if such be the case to report accordingly.

The effect of a favourable finding on the part of the inspector will be, firstly, to enable the contractor to withdraw his men and hand over the plant to the purchaser's own employees, and secondly, that the proportion of the purchase money payable upon "setting to work" becomes due forthwith. It is, therefore, a matter of some concern to both parties, and both will, it is needless to say, keep a watchful eye upon the doings of the inspector.

Supposing that he has strictly carried out his examinations during construction, the materials and the workmanship are necessarily beyond reproach, while the dimensions and the design, whether beyond reproach or not, are certainly at this stage beyond alteration. There is, in fact, nothing left undetermined except the efficiency of the plant as a whole. The methods of ascertaining this, though a lengthy sequence of observation, demanding a certain degree of skill and a good deal of time and patience, are yet but a series of well-



COMPLETE INDICATOR OUTFIT. SCHAEFFER & BUDENBERG, MANCHESTER

organized steps, each one of which is, taken separately, perfectly capable of demonstration, as we shall presently see.

All minor difficulties such as are incidental to the starting up of a new pair of engines have naturally been smoothed away by the contractor's men during the time the plant has been running under their charge. The person appointed to conduct the efficiency tests,—here designated the inspector,—does not expect that his time will be taken up by having to search for and point out small deficiencies, although, as his certificate will cover the fitness of the whole plant for taking up its life-long work, it will be his duty to see all parts in perfect order before he can venture to leave the place.

His trained eye, from the moment of his arrival, is continually on the alert, and from his previous acquaintance with every part of the engines and boilers there is little that escapes his notice.

His practiced hand, by a touch of each moving rod, by a casual "feel" of each eccentric strap and bearing, conveys to him, with a certainty born of long experience, the precise condition of the wearing surfaces. He notes whether the engines are solidly fitted down upon the massive capstones of the foundation masonry; whether each holding-down bolt is pulled up tight, so that no "working" (betrayed by the lapping in and out of a film of oil between the engine beds and the stone work) can possibly occur.

As the piston-rods race to and fro through their stuffing boxes the touch of a finger (duly protected from the heat) on the gland will reveal by an almost imperceptible up-and-down motion any fault in the "lining-up" of the trunk guides and cylinders, while the smallest departure from perfect squareness in the putting down of the engines manifests itself by a tremor or slight jar sideways in the connecting-rods, unmistakable to the touch. And so it is all through as regards the external and visible parts of the engine.

There are few constructional imperfections in the slightest degree affecting the working of the engine which can stand the test of a few days' running without displaying easily recognizable symptoms. We will suppose that, as far as can be ascertained from a careful and systematic external examination, the whole of the plant,—engines, boilers, condenser and air pumps, steam and water connections, separators, drains and steam traps, with the numerous auxiliary appliances of every kind,—are in perfect working order, and free from visible defects, and that the lubrication is amply provided for.

The ability of the governor to maintain the speed of the engine un-

altered, save within the specified limits, under different conditions of load, is satisfactorily demonstrated, and the efficiency of any safety appliance designed to prevent racing in the event of the governor failing to act being proved by actual test, we are free to embark upon the somewhat lengthy series of tests relating to efficiency and steam consumption.

"Efficiency" in the sense to be here understood, is the proportion which the power given off at the fly-wheel bears to the total power developed. This is a permanent figure inherent or peculiar to each individual engine, being, in fact, the measure of the power required to maintain the whole of the reciprocating and revolving masses in motion at the specified rate, and is always expressed as a fraction of percentage of the indicated horse-power.

In cases where the size of the machine admits of such a method the efficiency is measured by simultaneous observations of the gross and net power developed. A friction brake, loaded to represent the actual horse-power desired, is applied to the fly-wheel, and at short intervals during the time that the weight is suspended a series of indicator diagrams is taken. The mean effective pressure deduced from each card by the planimeter or otherwise is then averaged, and from it the figure denoting the indicated horse-power corresponding to the load of so many brake, or effective horse-power, is calculated.

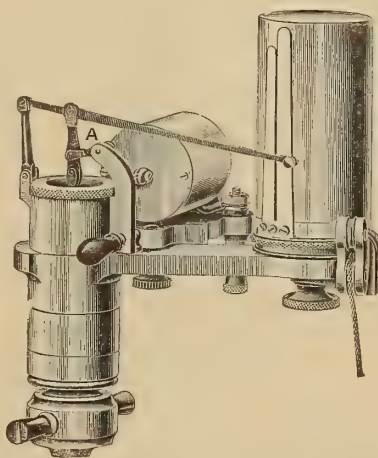
The ratio $\frac{B. H. P. \times 100}{I. H. P.}$ is the

percentage of efficiency.

It is obviously impossible to apply the brake test to engines of any magnitude; hence we must measure the power required to keep the unloaded engine in motion at the proper speed by means of the indicator. The mean I. H. P. calculated from a series of fractional diagrams and subtracted from the total ascertained indicated horse-power gives the ef-

fective or brake horse-power, and thence the efficiency, as before. This method, though not amounting to a positive determination of the problem, is nevertheless sufficiently accurate for practical purposes, and indeed is the only alternative to actual measurement by brake.

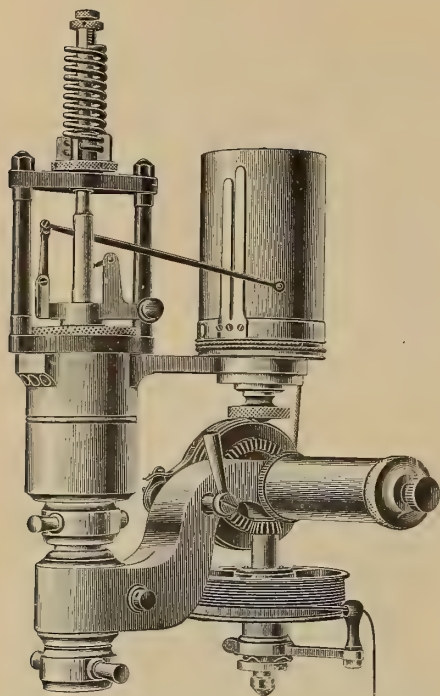
The total internal resistance of the engine, as measured by the mean effective pressure shown upon the unloaded diagrams, is made up of at



CROSBY ENCLOSED-SPRING INDICATOR. CROSBY
STEAM GAUGE CO., BOSTON

least three separate items, though commonly spoken of in the lump as engine friction.

There is the engine friction proper, there is the atmospheric resistance (which in a large engine may amount to several horse-power, particularly if the flywheel be left open), and there is the power absorbed in maintaining the heavy rotating and reciprocating weights at full speed. A consideration of these separate factors will show that the time for taking the unloaded cards for efficiency calculations should be carefully chosen. The two latter resistances, taken together, form a constant, inherent or peculiar to the individual engine at its proper speed throughout its career, while the first-named gradually lessens from the time the en-



CROSBY EXTERNAL-SPRING INDICATOR, CROSBY
STEAM GAUGE CO., BOSTON

gine is first started up until, in common parlance, it has worked itself to its bearings.

It is customary, therefore, to allow some weeks to elapse before taking the friction cards, where such a course is possible, or otherwise to make an adequate allowance. It would be manifestly unfair to the maker to found any calculations for efficiency upon results derived from an engine just out of shops.

Again, granted that the engine has fully settled itself in its bearings, and everything, as far as can be seen, is in full working order, it is still possible to get inaccurate diagrams by choosing the wrong moment to apply the pencil of the indicator to the paper drum.

To obtain reliable data for efficiency the engine must have been running at its mean speed for some minutes; that is to say, neither acceleration nor deceleration must be taking place. If the former, the

diagram will record the temporary effort to regain the normal speed, if the latter, part of the work is being done by the stored-up energy in the flywheel, and the cards will show less than the proper figures. If the pencil be held to the card for five or six successive revolutions, and it continues to trace an identical line, the diagram may be accepted almost without question as the true measure of the sum of the internal resistances, within the limits of error pertaining to the particular instrument employed.

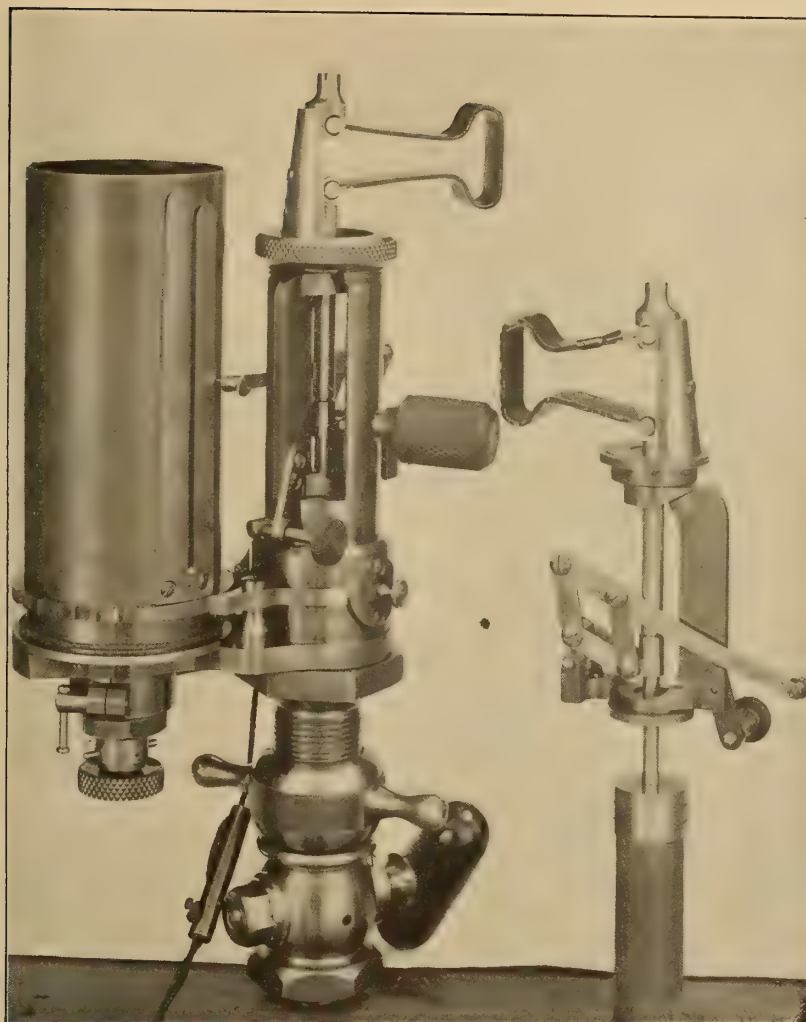
All this may seem, at first sight, a pedantic insistence upon petty detail; but the determination of the efficiency ratio may be a very important point in the contract. It cannot be found within reasonable limits of accuracy unless the greatest care is taken to eliminate all disturbing influences, and the contractor is entitled to proper facilities for enabling him to demonstrate that his engine resistances are within the terms of the specification.

An error of half a pound in recording or computing the low-pressure diagram will quite probably make a 2-per-cent. difference in the result, so that unless the conditions are in every way favourable for a fair trial it is not worth while to attempt it.

A good guess will probably be quite as near the actual figure, and will save much fruitless expenditure of time and trouble.

The full-power trial, fortunately, is attended with far less difficulty. The necessary conditions are more easily attainable, and errors of observation are not only less likely to occur in themselves, but are merged in a probably tenfold greater total developed horse-power.

During the period of probation, while the engines and plant generally are under the hands of the contractor, indicator diagrams will have been frequently taken, at first for the purpose of setting the valves, later for approximately balancing the cylinders; or, in other words, so ad-



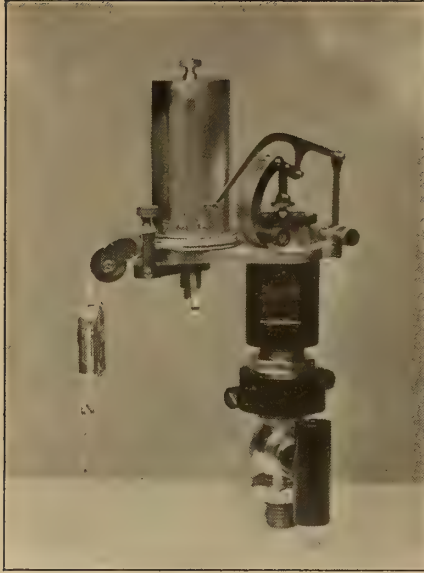
THE SIMPLEX EXTERNAL-SPRING INDICATOR. MESSRS. ELLIOTT BROS., LONDON

justing the cut-off in the low-pressure cylinder that, at the prevailing load, the indicated horse-power of each cylinder shall be practically equal.

When the contractor, through his responsible erector, declares the diagrams to be as near perfection as he can get them, then, in a double sense, the inspector's trials begin.

Many and various are the faults for which the lines of the diagrams have to be scrutinized, and, as a general rule, the more glaring the error,

the more easily it is rectified. What may be called the rudimentary faults we may suppose to have been already dealt with by the erector, and the cards presented to the inspector's scrutiny show equal cut-offs, due compression, and a proper amount of lead, with a release neither too early nor too late. Further, the vacuum is continuous and satisfactory, i. e., it fulfills the requirements of the specification, having regard to the temperature of the cooling water supplied.



ENCLOSED-SPRING INDICATOR. DOBBIE-MCINNES
CO., GLASGOW

There are two classes of incidental defects which must be looked out for and eliminated if they exist, viz.:—errors in the instrument itself and in the means of connection.

Firstly, the indicators, together with the pressure and vacuum gauges used for the trial, must themselves be properly equilibrated and in proper agreement. As much may depend on the result of the test, and as—in the event of a report unfavourable to the contractor being arrived at—it would be perfectly in order for the latter to challenge the accuracy of the instruments employed, it is very desirable both parties should agree beforehand that the indicators used in the trial should be accepted as correct.

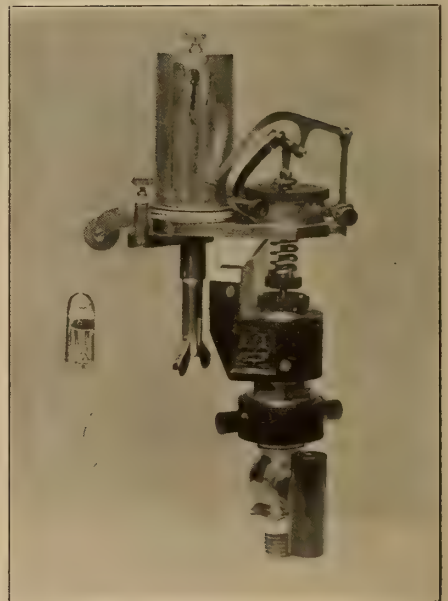
Secondly, as to the methods of connection. Though not quite approved in theory, convenience suggests the principle of a central three-way cock with a pipe from each end of the cylinder.

But the pipes and the cock must be of ample size and free from sharp turns, so that the changing pressures upon the main piston, as it rushes

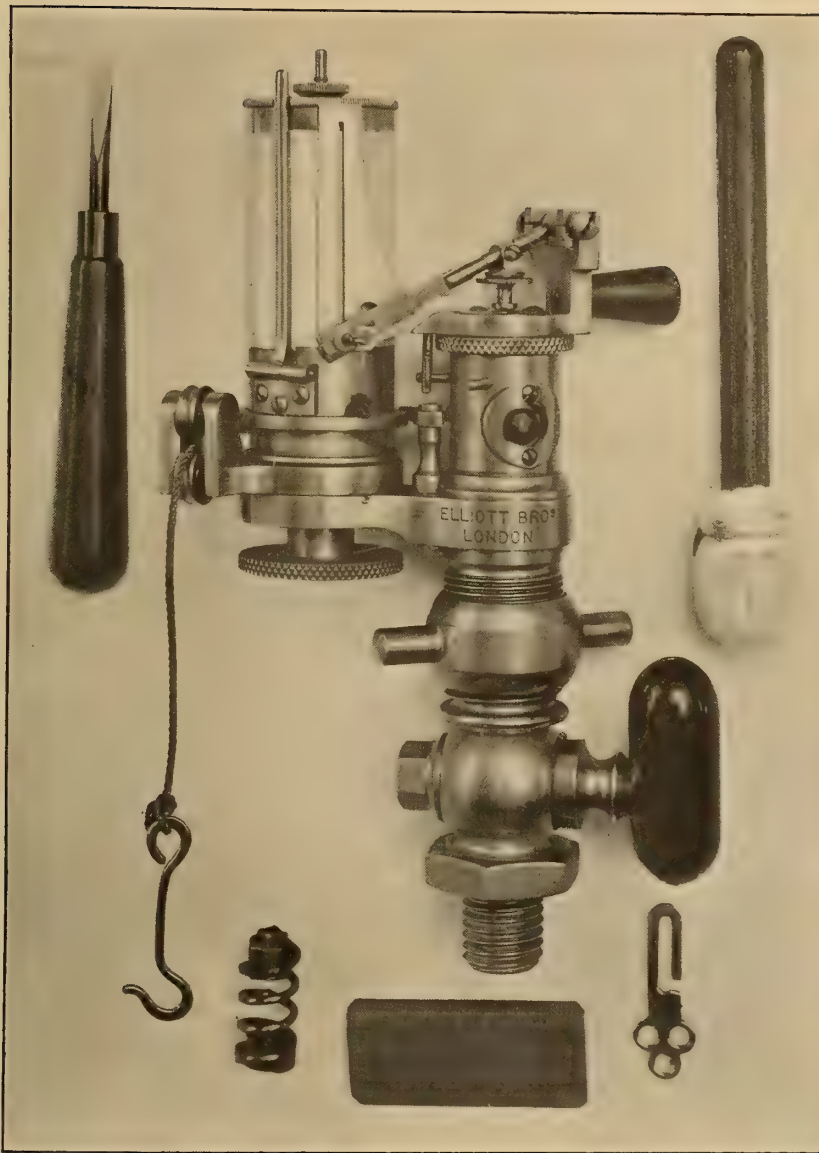
back and forth at a mean rate of six or seven hundred feet per minute, shall be faithfully reflected upon the diminutive piston of the indicator.

Simple enough this, but it is also necessary that the same motion of the piston shall be accurately reproduced to a reduced scale upon the paper drum of the instrument. But every reducing gear is capable of effecting this properly. They may be classified under the three general descriptions, pendulum, pulley, and pantograph gears, of which it may be briefly stated that the latter, if rightly designed, and with the cord led away in a direction parallel with the piston rod, is geometrically correct, though somewhat liable to back-lash on account of the number of working joints involved.

Pulley, or coiling, gears, if dependent upon a spring for the draw-back motion, are not desirable for high piston speeds, though convenient in application. Probably the best arrangement is the pendulum gear from a fixed fulcrum, its lower extremity being connected to the cross-head by



EXTERNAL-SPRING INDICATOR. DOBBIE-MCINNES
CO., GLASGOW



DARKE'S INDICATOR FOR HIGH-SPEED ENGINES. MESSRS. ELLIOTT BROS., LONDON

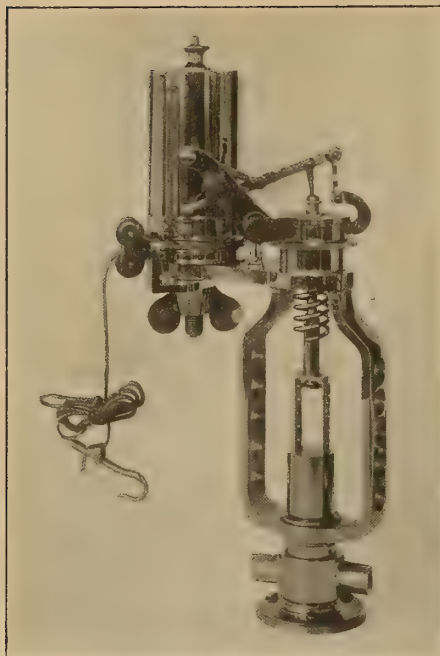
a coupling rod as long as can conveniently be got in, and so placed that while the pendulum swings through equal area on each side of the vertical centre line, the coupling rod oscillates through equal arcs above and below the horizontal.

A short arm, adjustable for length and angular position (not a circular

sector), should be employed for actuating the indicator cord.

Assuming the indicator to be fixed at the centre of the cylinder's length, the cord will rise from the small guide pulley on the instrument at a tolerably steep angle to the lever arm just mentioned.

The virtual length of the latter



EXTERNAL-SPRING INDICATOR. SCHAEFFER &
BUDENBERG, MANCHESTER

is easily adapted to the stroke required for the paper drum, and its position is rapidly and correctly found by holding the cord at full stretch and adjusting the lever arm so that the pin on which the cord will be presently hooked just touches the under side of the cord at both ends of its movement.

This is done, and the arm secured in position, while the engine is running.

Given that the length of the pendulum is not less than one and a half times the stroke of the piston, and that the cord is inextensible, a correct reduction may be predicted. There are two minor, but very common, sources of error in indicator movements to be guarded against, viz.:—the presence of an elaborate and weighty device for adjusting the length, placed somewhere near the middle of the cord, and an insufficient amount of strength in the drum spring.

Both of these are liable to destroy

the diagram at anything beyond very moderate speeds. The latter, owing to the momentum of the paper drum, causes it to overrun at the end of the outward stroke and to delay on the return, while the former, from the tendency of the cord to "whip" through the weight of the adjuster, accentuates the evil, with the result that the diagram is, so to speak, too long at one end.

Many makes of indicator are now fitted with a helical drum spring, which can easily be adjusted for strength, in place of the old "clock-spring" movement, giving a far more uniform pull on the cord.

If any doubt arises as to the correct length of diagram at full speed, it can easily be verified by simply slowing down the engine and comparing on the same card the length under the two conditions.

We may have dwelt at inordinate length upon the mere preliminaries to the actual test, but it is only too probable, after taking all possible precautions to eliminate known sources of error, that we cannot hope for more than an approximation to the truth, say within one or perhaps two per cent. above or below the actual figure.

It is evident, therefore, if the expense and trouble of a test be gone to at all, that the utmost care in the preparations should be taken.

It is exactly the man who is slovenly in his preparations and not too particular in his detail results who is most likely to produce with the utmost confidence a report bristling with figures calculated to three places of decimals.

Again, we must keep to the terms of reference in this matter, which may be, shortly stated, thus:—the contractor has constructed and put down a certain steam engine with its boilers and all necessary apparatus connected therewith, under a guarantee that the consumption of steam or of coal is not to exceed a stipulated number of pounds of steam or coal per indicated horse-power per hour.

He now claims to have completed his undertaking, and presents the whole plant for verification or otherwise of the fulfillment of his contract.

There are no side issues. The inspector is not called in, for example, to determine the causes of any shortcoming in the result, nor to suggest any alterations which, in his view, would be an improvement. His position, in fact, is exactly that of the examining medical officer to a life insurance company, in whom it would be a breach of etiquette to prescribe for the ailments of a candidate sent to him for examination. The inspector has simply to ascertain on behalf of the purchaser by whom he is, directly or indirectly, employed, firstly, the average indicated horsepower developed during the period of the test, and secondly, the total weight of feed-water and of coal consumed during the same period.

A few hours' test, taken over part of the day when an uninterrupted run can be secured, will be amply sufficient to determine the points at issue.

On the day appointed for the full-power trial the factory or works for which the new motive power is designed will be in full operation, or so near it that the engines will be developing approximately their contract power.

From the time of commencing the trial indicator diagrams should be taken at stated intervals, simultaneously from both cylinders (or from all the cylinders, if there be more than two), and preferably with the pair of diagrams on each card. These intervals may be of ten, twelve, or fifteen minutes, if the load is comparatively uniform and the speed fairly constant. The cards, as they are taken, should be placed in pairs or sets and the following particulars recorded on each, viz.:—The time (A. M. or P. M.) at which the diagram was taken; the observed revolutions per minute; the steam pressure at the stop valve; the receiver pressure; the vacuum; the temper-

ature of the injection water, and that of the hotwell.

During the test no valve setting or readjustment should be permitted; the diagrams for the moment are only to be regarded as a means of obtaining the mean effective pressure upon the pistons.

It is obvious that extensive errors might be set up, affecting the final result proportionately to the size of the engines under test, unless some means of estimating the rate of revolution other than ordinary counting were employed. The indications of a carefully calibrated fixed tachometer are useful for noting slight fluctuations in the rate, but the only absolutely trustworthy instrument is the ordinary consecutive engine-counter.

Starting from zero, or from a known number, at the beginning of the test, the total number of revolutions made during the whole period is faithfully presented, and that number divided by the number of minutes' duration of test, will give, with an accuracy beyond dispute, the mean rate of revolution per minute. While,



ENCLOSED-SPRING INDICATOR. SCHAEFFER & BUDENBERG, MANCHESTER



CONTINUOUS-DIAGRAM INDICATOR. MESSRS. DOBBIE-McINNES CO., GLASGOW

therefore, the tachometer rate should be noted upon each indicator card, the mean rate above mentioned is the only value which should be used in computing the horse-power; if the rate is a continually varying one, no approach to accuracy is obtainable by this or by any method known to the writer.

We will suppose that sixteen sets of cards have been taken without obvious error (such as would arise from the sticking of the indicator piston, for example), and that nothing has occurred to mar the test.

An assistant, armed with a planimeter, or diagram averager, has rapidly computed the mean effective pressure of each pair of diagrams, and has tabulated the same.

It only remains to multiply the average of all the mean pressures for each cylinder by the mean rate of revolution and by the constant:

$$\frac{\text{Area in sq. in.} \times \text{ft. per rev.}}{33,000}$$

Adding the two results, we have the total I. H. P. as nearly as it is possible to obtain it; certainly with a probable error not exceeding one per cent., if all the precautions we have enumerated have been taken and the load is fairly uniform.

Having now an accepted figure for the indicated horse-power, we have only to consider at what cost in steam and in coal it has been obtained. Ours is a purely commercial investigation. There are, from the

purchaser's point of view, no complications to interfere with a straightforward answer to these two questions. But there is every necessity for the most scrupulous care in the preparations.

We have, in the first place, to measure all the feed-water into the boiler for a period of, say, four hours, more or less.

The least troublesome method, if the quantity to be dealt with is large, is obviously the simple plan of passing it through a water meter temporarily connected up to the main. But the avoidance of a little trouble is dearly bought at the cost of accuracy, and a more positive and definite means of measuring is to be preferred.

The twin-tank system, though needing constant and responsible attention throughout the test, has the merit of reliability.

Two open-top tanks, having an overflow pipe fitted to each, are fixed up on temporary trestles. Overhead is a water supply cock, having either a swivelling arm or a short length of india-rubber tube attached, so that either tank can be filled from it.

Below is a third tank, or cistern, of similar size, from which the feed pump, for the purposes of this trial, draws all its water, and into which either of the overhead tanks, by a bottom valve or cock, can be discharged at pleasure. These should be conspicuously numbered 1, 2, and 3, and constitute the whole of the necessary apparatus.

When, and not until, the tanks are fixed in position, the actual quantity to be debited to the boilers each time either tank is emptied may be ascertained by very carefully weighing, once for all, the water which will run out of each after the overflow has ceased to drip. That this will be something over or under the nominal quantity is certain, but it is perfectly immaterial so long as the weights, whatever they may be, are accurately recorded for No. 1 and No. 2, respectively.

The height of the water-level in the boiler, or boilers, at the beginning of the trial must be carefully observed and its position determined by a temporary pointer attached to the gauge fitting, or boiler front. The pointer must come quite close to the glass or a serious error in observation is likely to occur.

As an eighth of an inch of water, at the usual level, in a Lancashire boiler 8 feet in diameter and 30 feet long will amount to about 150 pounds, the most minute care in determining the levels at the beginning and end of the test is called for.

To avoid errors due to any accidental shifting of the pointer while the test is proceeding, its position in relation to some fixed point (usually a dot in the cleaning plug of the lower gauge fitting) should be ascertained and recorded.

At the moment of commencing the trial (care being taken to see that the pump feed-pipe and the economizer or feed-heater are all fully charged) the tanks 1 and 2 should both be full, and the exact level of the water in cistern 3 should be recorded. Tanks 1 and 2 are then alternately emptied into the cistern, a responsible man being placed in charge to note in the log-book the time,—to the nearest minute will do,—at which each separate tankfull begins to run out.

This affords a means of checking the total quantity at the end of the run, as a double interval through inadvertently missing an entry would immediately show itself. The temperature also of the feed-water should be noted from time to time.

At the conclusion of the test the total quantity of water passed through the tanks (inclusive of the two which were full to start with and the water which was contained in the cistern) is booked up, and from it is to be deducted the weight of all the water collected from the steam traps, jacket drains, or leakages.

This total again has to be corrected for the difference, if any, in

the water level of the boilers, at the start and completion of the test. It is, however, usually better, if possible, to run on a short time longer, until the water level is exactly the same as at the beginning. A few minutes more or less in the duration of the test is not an important matter. Whatever steam is used for driving the auxiliary plant, such as feed-pumps, mechanical stokers, or economizer scrapers must be deducted, in the form of an equivalent weight of water, from the amount debited to the main engines.

These auxiliaries will, of course, have been tested beforehand, so that no delay may ensue in making up the net total immediately after the close of the test.

Now we have:—

$$\frac{\text{Total net lbs. water} \times 60}{\text{Av. I. H. P.} \times \text{length of test, min.}}$$

as the actual steam consumption in pounds per indicated horse-power per hour. This is the plain, simple fact to be elicited, so far as the maker's contract is concerned with the engine. The efficiency, in terms of a percentage of the total power developed, we have already dealt with.

The remainder of our investigation concerns the boilers alone, and resolves itself into the ascertainment of the water evaporated per pound of coal.

The feed-water is supposed to be supplied at 212 degrees F. and to be evaporated at atmospheric pressure, and the fuel is assumed to be coal (such as "Nixon's Navigation" or other best Welsh coal) having a calorific value of 15,000 British thermal units per pound weight.

A single weighing machine is placed in the stoke-hole with the platform either level with the ground or provided with temporary inclines for convenience of using a wheelbarrow. The weight of the barrow is balanced by improvised weights placed on the steel-yard, so that each load can be rapidly weighed without deduction.

The fires should be cleaned and evenly spread over the bars just before the start, which is timed to begin from the moment of shutting the doors after the first firing-up.

Care should be taken in this case not to vitiate the test by loading up the fires too heavily and thus causing a fall in the steam pressure, which must be maintained at the full working pressure during the whole time of the test. But on no account must any steam be lost by "blowing off" at the safety valve.

Some manipulation of the fires may be required towards the end of the trial to bring them gradually to the condition from which they started, viz.:—cleaned and evenly spread, and burned down as nearly as possible to the original thickness. As previously stated, when speaking of the water-level, the duration of the trial may be extended for a short time to allow of this being done, notice, of course, being given to the engine room not to alter the load.

The test being declared at an end, any coal left on the floor plates is weighed back and credited, and the weight of the coal actually fed into the furnace officially recorded.

We credit the boilers with the total weight of water evaporated (without deduction for auxiliaries) to find the rate, thus:—

$$\frac{\text{Total gross lbs. water} \times 60}{\text{Total lbs. coal} \times \text{length of test, min.}}$$

If the feed water is not at 212 degrees F., the result is to be corrected by multiplying by the factor of evaporation corresponding to the actual temperature, as found in any of the engineering pocket books, or as determined from the ratio of the total heats for the two temperatures involved. If coal of a lower calorific value than 15,000 B. T. U. is used, the result should also be corrected by multiplying by the ratio of the two thermal values, and thus any existing conditions may be reduced to the standard, and the results rendered comparable with others.

THE PACKING OF MACHINERY FOR EXPORT

By W. E. Partridge

It is becoming recognized that there are other elements involved in the successful development of export trade in machinery, besides excellence in the product, although that naturally must hold the prime position. Many an excellent article has failed to find or maintain its place in a foreign market because of defects in the manner of handling the trade, lack of observances of the business methods of the country, or because of the employment of such imperfect methods of packing that the articles arrive at their destination in a condition unfit for use. It is this last element with which Mr. Partridge deals, and his paper shows by illustrations of convincing clearness how even light and delicate articles and machines may be packed for foreign shipment in a manner at once secure and commercially practicable.—The Editor.



HOW to pack machines which are to be sent long distances and which have many transshipments by land and sea, is a problem which troubles most of the larger manufacturing establishments. Heavy claims for damage, resulting from breakage, urge extreme care and great precaution. On the other hand, expense stands in the way. The solution of the problem is, therefore, by no means a simple one, and a curious fact in connection with it is that there is little or no literature on the subject beyond the complaints of consuls.

Several years ago a paper upon the whole subject was presented before the American Chamber of Commerce in Paris by M. Paul Roux, this paper having been published in this magazine in the issue for July, 1904, his remarks being based on an extended experience in handling foreign machinery imported into France. M. Roux, however, was necessarily obliged to limit himself to general principles, the detailed methods depending very largely upon the nature of the object itself.

Absolutely nothing is to be found giving detailed instructions how any particular kind of machinery or merchandise should be packed. Each packing department has blindly to

search for methods. The weak point of this is that the person responsible for the method rarely sees the condition of the goods when they arrive at their destination. The only lesson taught is by inference that things are right when there are no complaints, an unfortunately rare event.

The broad subject of packing has almost as many subdivisions as there are manufactured articles. In this paper it is proposed to speak of a method which has been employed successfully in shipping over long routes self-contained machines weighing from 500 to 1500 pounds. It comes from the firm of John Royle & Sons, of Paterson, N. J., and is the result of years of experiment, study and costly breakage. It has finally been adopted in its present form for routers, drills, bevelers, column saws, planers, etc. Machines of this class are shipped complete, because, if taken apart, highly skilled labour would be required to successfully assemble them. These machines are self-contained, the frame usually taking the form of a rectangular column, with a broad flange at the base.

The first step is to protect the bare machine, Fig. 1 (a router), so that the painted parts shall be safe from injury, and all bright or finished work be protected from rusting. "No. 80 Cosmic" is used for this purpose. It seems like an impure vaseline, and hardens somewhat on the surfaces. When all the finished

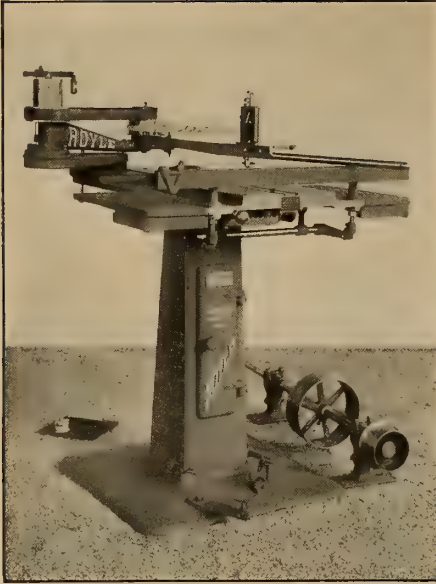


FIG. 1.—THE MACHINE TO BE SHIPPED

work has received its coating, the whole machine is packed and tied up in paper, as in Fig. 2.

The containing case is a heavily-built box made from $1\frac{3}{4}$ -inch spruce plank. This lumber has three important advantages for this purpose. It is light, strong and stiff, and it is also cheap. Lightness and strength are points of considerable importance. The case, Fig. 3, has a "round about," or edging, on both top and bottom. In the centre of the floor are four blocks. The base of the column and its flanges fit these blocks, so that the broad flange of the machine is raised from the planks of the case by perhaps an inch. This is a very necessary precaution. When the flanges rested directly on the floor of the case breakages of the flange frequently occurred from the natural elasticity and spring of the case. The blocking has remedied this.

The fundamental principle in packing is to hold the machine in the centre of the case and transmit blows or strains from side to side of the case without passing through the machine itself. By the system of bracing used this is almost completely

accomplished. The only exception is found at the point where the flanges rest upon the blocking, shown in Fig. 3. The strain is there taken through the flange, which is supported, however, on both sides.

When the machine is placed within the case, Fig. 4, a considerable clearance is given in all directions, an important point. To hold the machine in place, and at the same time prevent outside strains from reaching it, four heavy braces are employed. They embrace the column just below the table. These pieces are four inches by three, and extend across the case. Their edges next the frame are padded with paper. They are put in as shown in Fig. 5, and drawn together by the screw clamps so that they grasp the frame firmly. This is done to enable four coach screws to be put in from below to hold them permanently. When the coach screws are set home, the clamps and battens are removed, and a stay put in at the ends, notched to take the braces, nailed to the sides, and the nails clinched outside. Around the base blocks are cut in to prevent that part



FIG. 2.—THE MACHINE WRAPPED, PREPARATORY TO PACKING IN THE CASE



FIG. 3.—PACKING CASE, SHOWING CLEATS AND BATTENS

of the machine from moving, Fig. 6. It is also necessary to provide against the machine lifting. This is done by means of the long, upright braces. They are carefully padded on the lower ends with paper, and take a

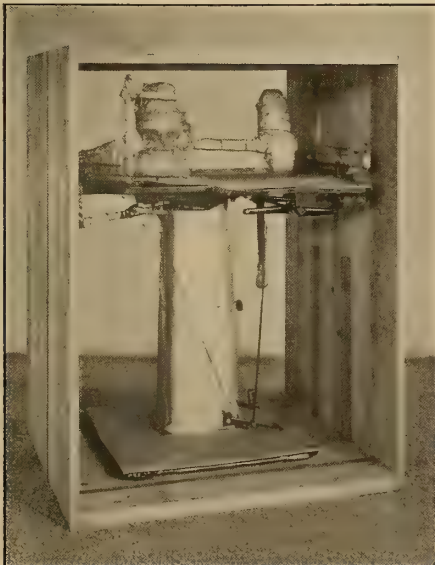


FIG. 4.—MACHINE IN CASE, SHOWING CLEARANCES

bearing directly over the blocks on which the flange rests, relieving the latter from strain.

The machine is now held in place in the cases, and braces are so arranged that strains or blows from any direction, and upon any side, are taken up by the case alone. To strengthen the case further another pair of stays is introduced to hold the ends of the other cross braces. These are also notched for the ends, and a notched board is nailed on top

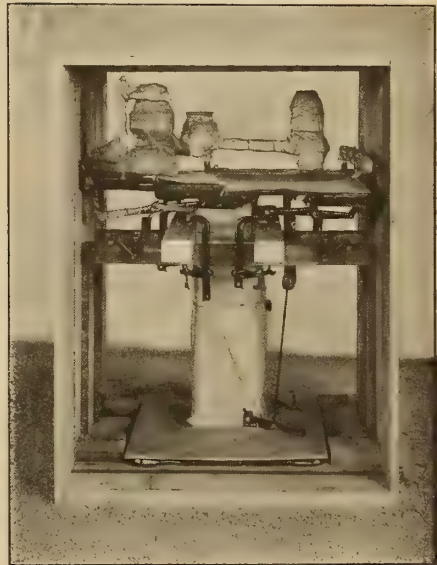


FIG. 5.—SHOWING THE BRACES TO PREVENT LATERAL MOTION

of them to make all secure, Fig. 7. In this figure the back is put on, and a flat, diagonal brace inside the corners is introduced from corner to corner.

The packing of pulleys and small pieces is often accomplished as shown. Castings are secured to the bottom of the case, and pulleys are held against the sides by single bolts, Fig. 8. Larger pulleys, and those with arms, have their hubs blocked away from the sides, so that the rims do not touch. This saves breakage caused by screwing up too tightly, or from springing of the planks.

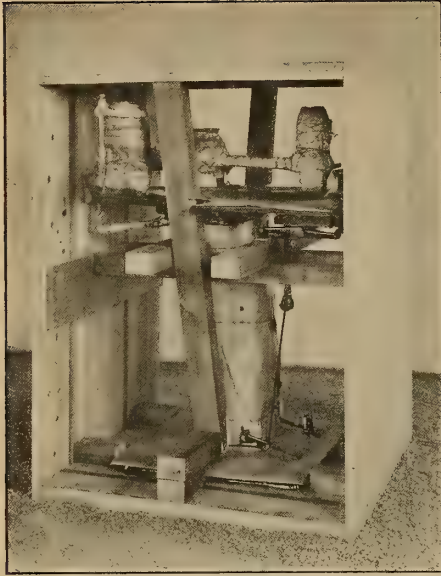


FIG. 6.—SHOWING VERTICAL BRACING

In a case of this size, say 5 feet high by 3 feet square, three rows of banding are necessary. And in order to secure the two open sides edging or "round about" is used, not only on top and bottom, but on two sides.



FIG. 7.—CROSS AND DIAGONAL BRACING, PACKING OF SMALL PARTS

This is shown as begun in Fig. 7 and completed in Fig. 8. The latter figure shows everything in place and nailed fast, ready for closing, and the next figure shows three of the front boards nailed in place. The greater part of the nails used in making this case are what are known as "20 penny." They are 4 inches long and proportionately heavy. They are used in putting the sides together, and wherever there is a sufficient substance to receive them. For the

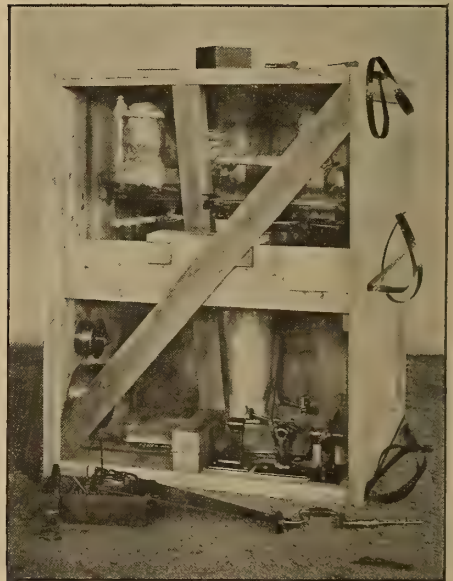


FIG. 8.—THE CASE READY FOR CLOSING

blocking and some of the light pieces smaller nails are sufficient. In the boards used for covering in the two sides a double row of the "20 penny" size is used. One row is driven into the edging and the other into the boards of the case.

In closing the case the boards are all nailed in place, except the two standing in front, Fig. 9, which are put on with screws. This is necessary in order to give a practicable opening in beginning to unpack, and to permit an examination of the contents by customs officials. Without this precaution entrance would be-

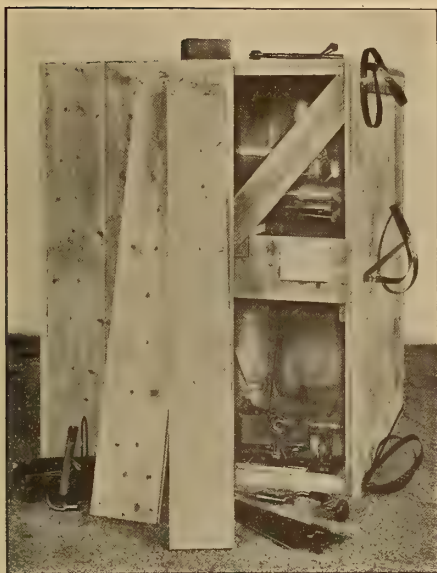


FIG. 9.—SHOWING THE TWO BOARDS TO BE SECURED WITH SCREWS TO FACILITATE INSPECTION AND OPENING

come difficult in the extreme, and injury to the contents would be almost unavoidable.

The completed case, Fig. 10, has three lines of steel banding, the two boards are screwed in place, and the work of packing is complete. In this figure can be noted the heavy nailing of the boards at top and bottom, and the three "20 penny" nails driven into the ends of the braces as extra precautions. The positions for these nails are obtained by measurement; missing the timber is out of the question.

On the outside of the case near the covering boards will be found a small placard put on with shellac, and another copy is seen on the stay or cross brace, Fig. 9. These give directions for the easiest and safest method of opening the case. The following is a copy:—

"UNPACK THIS CASE CAREFULLY

"First remove the steel banding. You will then find two boards which have been put on with wood screws. Remove these, then with a sharp saw

cut away the remaining front boards top and bottom. Cut the diagonal brace which extends from corner to corner of the case and pull it out.

"Remove the castings screwed to the sides and bottom of the case. Pry up and remove the board nailed flat upon the timbers in front. Then with a sharp saw cut off each end of the stay running across the case (the one with these directions on it). Remove it.

"The four heavy braces around the column are held together by coach screws on the under side. Take these screws out. Next saw the two upright braces through just below the level of the table. Take out the blocking about the base of the machine.

"The front brace and the lower end of the one in the rear can then be removed. Saw the front cross brace near the ends and take out the central part. The machine can now be taken from the case by lifting the front edge a couple of inches to clear the central blocks.

"Avoid the use of hammers, crow-bars or similar tools in removing the casing. The method indicated is not

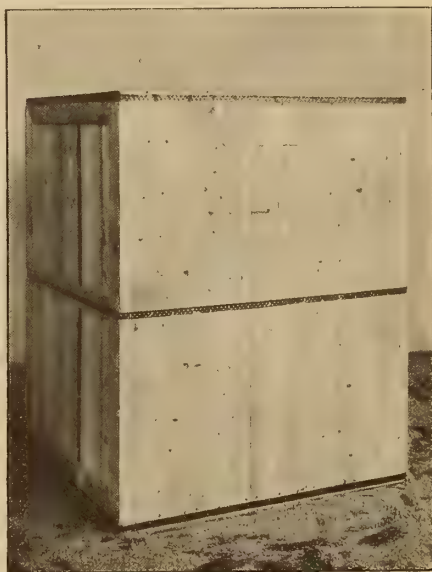


FIG. 10.—THE CLOSED CASE



FIG. 12.—PACKING SMALL ARTICLES

only the easiest, but the safest method. Use every precaution not to wrench or strike the machine.

"Before packing, the machine in this case was inspected, and was in perfect order. The case is strongly and carefully made, and, in order to avoid breakages, must be cautiously removed. Bad unpacking is a frequent cause of breakage, causing annoyance and expense to the purchaser of the machine.

"It is important that the above instructions be strictly and intelligently followed.

"JOHN ROYLE & SONS,
"Paterson, N. J., U. S. A."

Marking is not strictly a part of the subject of packing, but it is so intimately connected with it that another engraving, Fig. 11, is given to show the case ready for the steamer. As much as possible of the marking is done with a stencil. Some firms go so far as to stencil all their marking, a plan which is desirable, but not always practicable. Its legibility gives it a great advantage over the

brush. The long arrow, a somewhat unique way of indicating the top of the case, is remarkably conspicuous, as well as unmistakable.

That this system of packing through



FIG. 11.—SHOWING METHOD OF MARKING

a long series of years has been remarkably successful in resisting the vicissitudes of difficult and trying voyages, is sufficient proof that the embodied ideas are worthy of careful study.

Going to the opposite extreme of size and weight from the machine just described, we have the air valve of the Norwall Manufacturing Company, of New York. The valve itself weighs only a few ounces, and is 3 or 4 inches in length. From one side a stem projects, and from this there is a still further projection of a bent tube *A* in Fig. 12. To carry this safely, a bottomless box *B* is made from a good quality of binders' board. The large part of the stem of the valve goes into the larger hole and the bent tube is held by the smaller hole. To protect the enlarged upper portion of the valve, another box without a bottom (shown at *C*) is placed over the valve. The half circle is cut from one side, so that it may straddle the side arm of the valves and at the same time take a firm bearing on the box *B*. The two boxes, *B* and *C*, with the valve in place, are a snug fit into *D*, and when the cover *E* is in place there is no rattle nor shake perceptible. All the parts are of a light-coloured binders' board, very strong, stiff, and beautifully straight and smooth. It will be seen that the sides are as true as though made of thin wood. All the important corners and edges are strengthened by cloth strips.

When the valve is in its box and the cover *E* is put on, it occupies just half the space in a larger box *F*. At *G* one of the larger boxes is shown, with its cover off, and one of the boxes *H*, holding a valve, in place. Each of the larger boxes holds two valves, and when the covers are on, as at *F*, the fit of all parts of the nest of boxes is so good that no "shake" seems possible. Packed in suitable cases, it is difficult to imagine how any harm could come to one of these valves short of an



FIG. 13.—AN EXAMPLE OF POOR PACKING

utter destruction of the firm outer case.

It is evident that a packing of this kind is much superior to one in which excelsior, straw, sphagnum or any soft packing is used.

The boxes, when assembled in a case of proper size, go in like so many blocks of wood,—and with no more danger to the contents.

We cannot refrain from giving one example of most scandalous packing of an especially fragile article. A firm which makes ginger-ale and puts it up in quart bottles, sends out dozen and two-dozen cases with only a sheath of corrugated straw-board to protect the glass. What the straw-board sheath looks like after it has been in service, is shown in Fig. 13. The breakage is large,—five or six bottles in a two-dozen case is not uncommon.



Current Topics

WITH the development of hydraulic power resources, made possible by the application of the electrical transmission of energy, the great waterfalls of the world have taken on an added interest for the engineer. With Niagara already utilized, and with the Victoria Falls already well in hand, we feel sure that the account of the great cataract of the Iguazu, described in our leading article of this issue, will attract interested attention. It is difficult to make comparative statements about these great natural sources of energy, owing to the number of variables involved, and because of the difficulty in obtaining precise data. Even in the case of Niagara it was not until its utilization was seriously considered that reliable measurements of the various elements of the problem were made, and in the case of the Victoria Falls and the Falls of the Iguazu precise figures are not yet wholly available.

Undoubtedly the Victoria Falls are the highest, the leap being about 340 feet, while the level of the water in the lower gorge is about 400 feet below the upper level of the Zambesi, but the volume of water is very variable and it has been maintained that the total amount of energy available is less than at Niagara, where the height of the fall is only about 160

feet. At Iguazu the leap is 210 feet, and while the volume of water has not been accurately determined, it is probably greater than at Niagara, although the rise of level in the lower gorge during the rainy season must act to diminish the effect of head for hydraulic power purposes.

That all three of these great natural wonders are to be extensively used for power purposes must be conceded, and experience with Niagara has demonstrated that a large amount of power may be diverted without materially affecting the appearance of the cataract. With modern methods of construction, power houses can be so placed as to cause little or no disfigurement of the landscape, and under judicious regulation the demands of industry and of æsthetics may each be satisfied without conflict.

THE epidemic of railroad accidents in the United States has naturally drawn forth a flood of comment, some of it to the point, and some rather wide of the mark. There is little doubt that the transportation facilities of the great railway lines are strained to the breaking point, not in every element, but in certain particulars corresponding to the weak links in a chain cable.

In nearly every case the terminal facilities are inadequate, as is evidenced by the great expenditures now being incurred to improve and extend them. This, naturally, is felt first by delays in handling trains and in consequent disarrangement of schedules, followed by the increased liability to accident when trains are no longer on their regular time.

The greatly increased demand for transportation has been partially met by the addition of longer, heavier, and faster trains, together with the use of heavier rails and strengthened bridges, but it is almost impossible to extend the operating personnel at the same rate as the mechanical equipment and at the same time maintain its efficiency at the maximum.

To meet the present demand for transportation, both in the passenger and in the freight service, involves what amounts almost to a reconstruction of the entire system of many lines. When to this is added the possible replacement, in important portions of large systems, of steam locomotives by electric traction, it will be realized that the railroad situation is not unlike the problem of rebuilding a great bridge without interrupting traffic, and that at a time when the traffic is greater than ever before.

It must not be assumed that this state of affairs is advanced as an excuse for the sad disasters and great loss of life which have been the subject of comment, but it is necessary that the situation should be viewed intelligently and thoughtfully if the permanent remedies are to be found. The pressure of the demand for transport cannot be met simply by putting more and faster trains upon existing roadbeds, using present limited terminal accommodations. To do so is simply to invite disaster, and it is better to meet with recriminations for inadequate service than to face the moral and financial responsibility of such a series of disasters as the past few months have recorded in the United States.

ONE of the points which has been made against the railways, and apparently with justice, is the laxity in operation of the block-signal system, carried to such an extent as practically to neutralize nearly all of the protection which it is supposed to afford. That an engineer should be permitted, under any consideration whatever, to run past a block signal, is to render that system far worse than useless, since its presence creates a sense of security which does not exist. If no signal system is installed, the very feeling of insecurity creates an individual degree of watchfulness, which gives some protection. When, however, a system, admirable in itself, serves to lull that watchfulness, while at the same time its value is practically destroyed by the violation of its fundamental principle, it is far worse than none. The first thing which should be done, if the railways of the United States wish to allay the feeling of insecurity which the recent accidents have created, is to announce, in unmistakable terms, that the block system is to be enforced absolutely, and to make that statement good beyond suspicion.

ANOTHER matter which has caused comment in connection with railroad accidents is the reported discovery of numerous rail breakages, this being partially attributed to the prevalence of cold weather. In this connection it may be worth while to recall the investigations of Mr. R. A. Hadfield upon the effect of low temperatures on various alloy steels. In his communication to the Iron & Steel Institute, Mr. Hadfield showed that many steels, when tested at the temperature of liquid air, showed a great increase in brittleness, but that certain alloys were not affected at all under such conditions of extreme cold. The alloy of nickel-manganese steel tested by him was remarkable in this respect, and it is possible that such a material may afford a solution of the rail-breakage question.

RUDOLPH DIESEL

By E. D. Meier

THE immense development of manufacturing industries in all civilized countries during the last three decades has called for constant improvement in the economics of prime movers.

The great step forward in the improvement of the steam engine taken by Corliss has been followed by numberless minor improvements in mechanical details, in compounding, and latterly in the use of superheated steam.

It was through the study of the thermo-dynamics of the steam engine, and with the hope of reaching, or at least approximating, the ideal cycle of Carnot, that Rudolph Diesel was led to make the great invention which is fast revolutionizing the economics of power production.

Rudolph Diesel was born of German parents, March 18, 1858, in Paris, and studied in the schools there until 1870, when the Franco-Prussian war made it necessary for his parents to quit France for England. They sent the twelve-year-old boy to Augsburg, in Southern Germany, where he entered the High School, and, graduating from that, continued his studies in one of the higher trade schools of that city. This school being under the patronage of the Kingdom of Bavaria, its graduates were examined by a State commissioner, who, in this instance, happened to be the president of the Technical College, of Munich. Diesel's intelligence and thorough grasp of the subjects he had studied induced this official to recommend him for further study, in which he gave him his earnest assistance. Diesel thus came under the influence of Professor von Linde, and, through him, was induced to make the new science of thermo-dynamics his principal study.

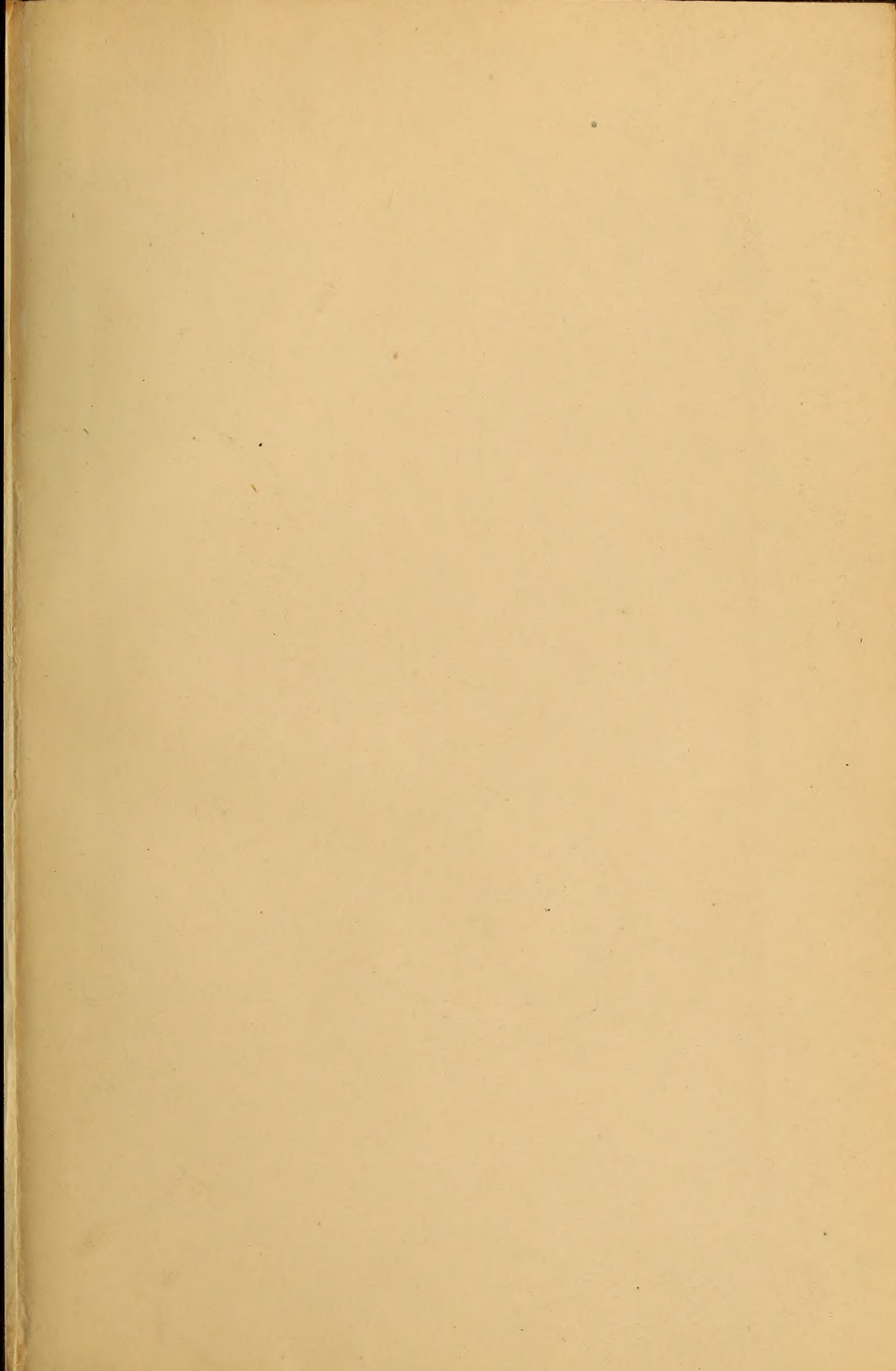
In 1879 he graduated from this college after a brilliant examination, and at once became assistant to von Linde in his practical development of the ice and refrigerating machines. After a short period of practical work in the machine shops of Sulzer Bros., in Winterthur, Switzerland, he was placed at the head of the French company for building Linde's refrigerating machinery in Paris.

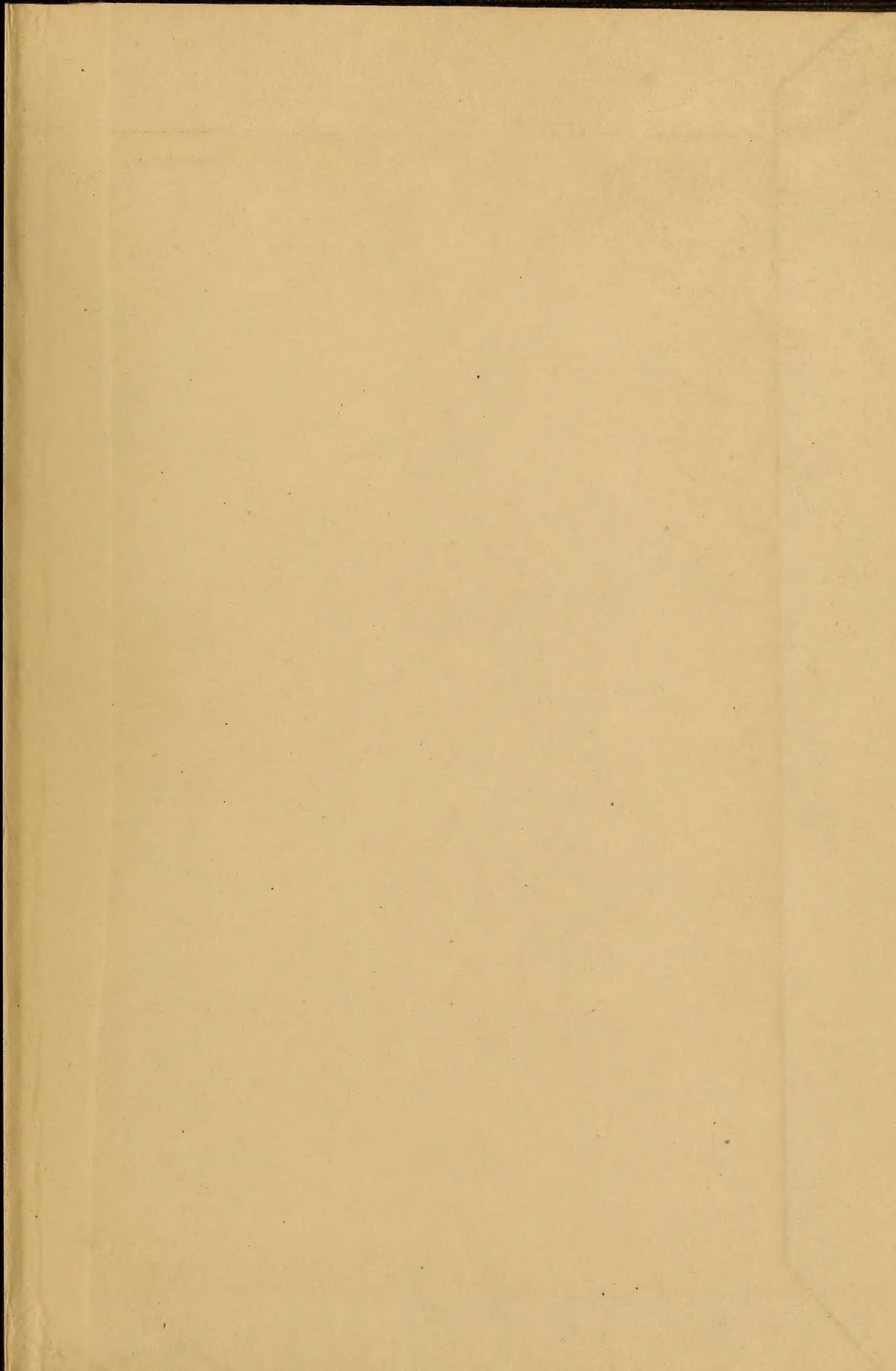
Having during his life as a student formed the definite plan of finding a prime mover of much higher thermal efficiency than the steam engine, he now found it necessary to be master of his own time, in order to continue his scientific investigations.

In 1893 he published his "Theory and Construction of a Rational Heat Motor." The extensive discussion created by this pamphlet drew the attention of Friedrich Krupp, the steel king, and H. Buz, the president of the Augsburg Machine Works, to his invention, and they placed means at his disposal for a practical development of his engine.

On June 16, 1897, he read a paper before the National Society of Engineers of Germany, describing a 20-horse-power Diesel engine working at Augsburg, and invited any and all present to test its efficiency for themselves. Many a doubting Thomas journeyed to Augsburg, tested the motor, and came back an enthusiastic Dieselite.

Since then the invention has been taken up by prominent engineers and mechanics in every civilized country of the western world, and thousands of Diesel engines are in daily operation, with a higher economy than the original Augsburg motor, and in powers ranging from 20 H. P. to 500 H. P. per engine.





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